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SOVIET GEODESY, CARTOGRAPHY, AND INSTRUMENTATION

NEW GEODETIC INSTRUMENTS
(Preliminary)

Compilation of Abstracts
Summaries and Extracts

AID Work Assignment No. 35
(Report No. 1 in this series)

Aerospace Information Division
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FOREWORD

This report, prepared in response to AID Work Assignment No. 35-2, is a compilation of abstracts, summaries, and extracts on new Soviet geodetic instruments. It is based on Soviet and Soviet-bloc open-source materials available at the Aerospace Insormation Division and the Library of Congress. Titles of Soviet monographs are transliterated, followed by the English translation. Library of Congress call numbers are included at the end of an entry when the item is cataloged and available in the collections of the Library. Soviet abstracts used in compiling this report are cited following original source entries. The data are arranged by general types of instruments and by specific instruments within groups. Tentative evaluations made by members of the staff of the Aerospace Information Division and partial translations or abstracts of papers giving Soviet evaluations of these instruments are presented. Supporting evidence is supplied in the form of translations or abstracts or papers describing field investigations and their results, and research and development of individual instruments or components. Photographs of major instruments and diagrams of their electrical, optical, and mechanical systems have not been included in this paper but are available for nearly all the devices described.

SOVIET GEODESY, CARTOGRAPHY, AND INSTRUMENTATION

NEW GEODETIC INSTRUMENTS

INTRODUCTION

Bases for Selection of Material

This report covers a selective cross section of the principal geodetic instruments used currently in the Soviet Union. Emphasis has been placed on instruments used for the higher orders of triangulation and leveling. No attempt has been made to provide a complete listing and description of all of the geodetic instruments used either in current operations or in earlier periods during which all, or almost all, of the USSR geodetic control data available in the United States were determined.

In selecting materials for this paper, the term "new" has been considered to have the following possible connotations: 1) new in the sense of the most recent; 2) innovations which obviously differ from instruments widely used either in operational principle or design or merely in the addition of new or improved components; or 3) instruments described by the Soviets as "new."

Types of instruments described in this paper include such conventional equipment as astronomic universals, theodolites, a phototheodolite, major levels, tachymeters, optical-mechanical range finders and the more recently developed, favored, and adopted light and radio range finders (Geodimeter- and Tellurometer-type instruments). Many instruments used extensively, directly or indirectly, in geodetic operations have been omitted from this compilation, e.g., gravimeters and magnetometers in the geodetic-geophysical field, and aerial survey cameras and associated photogrammetric equipment used to extend geodetic control (multiplex, stereocomparators, rectifiers). There is sufficient open literature on each of these instruments to prepare a report similar to the present paper should such a compilation be requested.

Additional information includes analogous descriptions of some of the types of geodetic instruments used and/or produced in the Soviet-bloc countries, chiefly Hungary, Poland, Czechoslovakia, and, especially, East Germany which acquired the former Zeiss Optical Company in Jena. No attempt has been made to compile a comprehensive report. Representative samples were selected because the information was readily available. Such descriptions frequently provide a body of information which can be used in comparing investigations of the same or similar instruments, and an insight into the role played by geographical or other physical conditions on the types of instruments developed or selected as being of maximum value in particular areas.

Summary Evaluation of Soviet Geodetic Instruments

Any evaluation of geodetic instruments made without access to the instruments themselves must, perforce, be tentative. Descriptions of instruments, optical and mechanical components, conditions at field test sites, methods and procedures of investigations, and analyses of results must be taken at face value and judged without first-hand knowledge of these factors, the quality of the training and competence of Soviet operators, and many other conditions of equal importance. Direct comparisons of instrument descriptions and reported results of operations with comparable equipment used in the United States are further complicated by the fact that the term "order" as used in the United States is not identical to the Russian term "klass" (which is translated as "order"). Throughout this report, references made to the "order" of measurements made with Soviet instruments apply to Soviet standards and requirements for "orders" of triangulation, polygonometry, etc. An English translation of the current official regulations for establishing geodetic networks of various orders in the Soviet Union is provided in Appendix B of this report.

Study of open-source Soviet literature leads to the following general conclusions relative to the present state of Soviet geodetic instrumentation:

1. The Soviets obviously attach considerable importance to geodetic problems in general, and to geodetic instrumentation in particular. This is attested to by the impressive volume, scope, and content of Soviet literature freely issued on these matters. Unlike their geodetic data which, according to the writer's knowledge, they classify as secret, information on instrumentation and field testing is readily available in many books, monographs, and periodicals.

2. Soviet geodesists keep abreast of current foreign developments in geodetic instrumentation. This is evidenced by numerous references in the literature to descriptions of European and Western instruments, reports of Soviet field tests of these instruments, comparisons of results of tests made with Soviet and non-Soviet instruments in identical areas, and the use of these non-Soviet instruments in several types of geodetic operations in the USSR

3. Conventional instruments such as universals, theodolites, and levels, used in the higher orders of triangulation and leveling networks of the Soviet Union, appear to compare favorably, both in quality and diversity, with similar equipment produced in the West (taking into account the requirements and standards of accuracy demanded by the Soviets in constructing triangulation, polygonometric, and leveling nets). Possible exceptions are some types of lenses, and refinements in the instrumentation of small parts (quality of tangent screws, filters, circle eccentricities, and similar components).

4. Open-source literature examined to date (1959-1963) contains no indication that the Soviet geodetic instruments currently in use are revolutionary either in design or operational principle. Improvements have involved attempts to refine lenses and to make changes in rod facings, radio frequencies, illumination, and methods of indexing, in much the same manner as Western instruments were evolved.

5. The only reference found to date in the open literature describing a different principle in geodetic-instrument construction deals with the invention of a metallic level which the inventor suggests would find application in geodetic and geophysical field work (see page 53 of this report). If this instrument has in fact been investigated by Soviet geodesists for its possible application to geodesy, no reference to it has been found in later publications.

Soviet Evaluation of the Status of Geodetic Instrumentation and Geodetic Network Development in the USSR

The article which follows gives a recent authoritative statement by a leading Soviet geodesist concerning the present status of Soviet geodetic instrumentation and the future requirements for geodetic network development in the Soviet Union. Portions of the article which relate to the purpose and scope of this report have been translated and are included here as background information.

Larin, B. A. New practices in topographic-geodetic operations. Geodeziya i kartografiya, no. 5, 1962, 3-7. QB275.G45

"At the present time the most important aspect . . . [of geodetic operations in the USSR] . . . is the construction of second- and third-order astronomic-geodetic and supplemental networks. Until recently such nets had been laid out almost exclusively by the triangulation method and the lengths of the initial sides had been determined from base networks or, under favorable conditions, directly measured with base-line apparatus using invar wires. With the appearance of phased geodetic range finders, based on the principle of the measurement of the time involved in the propagation of electromagnetic waves, the monopoly of the triangulation method was destroyed and there is reason to assume that triangulation operations eventually will be reduced. The use of precise pulsed-light* and radio** range finders results in significant savings and there is no doubt but that the primary effort in improving geodetic operations will involve their use.

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*Geodimeter-type instruments. **Tellurometer-type instruments.

"Light and radio range finders which are capable of measuring distances of from 25 to 30 km with high accuracy are required for laying out astronomic-geodetic nets. Such range finders have now been built. The domestic ЭОД pulsed-light range finder is capable of measuring the initial sides for first-order triangulation and polygonometry. When physicogeographical conditions are favorable, the lengths of first-order polygonometric sides also can be determined with the high-precision phased radio range finders developed by Soviet scientists . . . . In the next few years initial sides will be measured more and more in many countries with range finders just as first-order polygonometric traverses will replace chains of triangles of the same orders.

"The task of improving our light and radio range finders is now before the developers. The first item on the agenda is to improve the reliability of operation . . . . Improvements in design should be directed toward reducing the electric energy required to power the instrument and, consequently, to reduce the weight of the equipment. In improving radio range finders, the most important task is to use shorter wavelengths which reduce the effect of topography and the underlying surface on measurement results and thus increase their accuracy . . . .

"Light range finders also have been developed for use in laying out second- and third-order networks. Foremost among these instruments is the CBB-1 which for several years has been used to measure the sides of polygonometric traverses. Also ready for production is the СДД light range finder with an electronic presentation. This instrument assures high-precision measurements for distances of 15 to 20 km. In 1962 the СДД model will be tested in the field and in 1963 the first shipment will be issued to operational units. Further development of this instrument also will be made to improve its reliability and to reduce the power required for its operation . . . .

"Methods of measuring angles in triangulation are now well defined and one must assume that in the next few years no basic changes will be made in this type of geodetic operation. However, we must still work on improving the design of angle-measuring instruments. Currently, the basic triangulation instrument is the TT 2/6 theodolite. The accuracy of this instrument in measuring first-order triangulation and polygonometric angles is adequate, but it is cumbersome and difficult to transport. Therefore, we must build a lighter model which will still assure the required accuracy of angle measurements. The first models of the TBO optical theodolite were built at the Experimental Plant of the Central Scientific Research Institute of Geodesy, Aerial Photography and Cartography. This theodolite was improved and in 1962 a new TBO-2 theodolite model was investigated and tested. If this model meets all requirements it will be put into production next year. In addition, the OT-02 theodolite, now used to measure angles in continuous (unbroken) triangulation networks, is obsolete and requires a corresponding degree of modernization.

"In connection with the distribution of the astronomic-geodetic network over the entire territory of the USSR, the problem of coordinate control predominates, i.e., the establishment of several initial stations, the geodetic coordinates of which will have to be obtained with utmost precision from astronomic and gravimetric measurements. This problem is theoretically solved. High-precision astronomical instruments and methods of determining differences in latitude and longitude are required for the practical solution of the problem, as well as to determine the corresponding density of gravimetric stations. There is every reason to assume that the problem of coordinate control will be solved in the near future.

"In connection with the use of polygonometry for the construction of the State geodetic base, a somewhat more important role is played by Laplace azimuths because lateral displacement in polygonometric traverses is considerably larger than longitudinal displacement. In order to reduce lateral displacements, Laplace azimuths must be determined, in some instances, every 100 km (one additional determination per link). Geodetic azimuths can be obtained directly without resorting to the Laplace equation. Such a method was developed by Soviet scientists and was first put into practice in 1961. The AY 2/10 astronomic universal currently being used is obsolete and must be modernized in the near future . . . .

"No noteworthy changes are to be expected in the field of high-precision leveling in the next few years with the exception of the modernization of level design. The best prospects are for the design of a level with a self-indexing line of sight. Many systems of compensation for instrument tilt are being developed. However, our optical-mechanical industry is producing almost no such instruments. Use of levels of this type could noticeably accelerate productive work in running third- and lower-order leveling lines. Economic benefits to be derived by using such instruments for running first- and second-order leveling lines will be lessened considerably . . . ."

The following source contains critical evaluations by a Soviet specialist of photoelectronic and photographic methods and equipment used to determine geodetic positions in the USSR.

Yeliseyev, S. V. Fotoelektricheskiye i fotograficheskiye metody opredeleniya napravleniya na tsel' primenitel'no k geodezicheskim instrumentam (Photoelectronic and photographic methods of determining a direction to a target which are applicable to geodetic instruments). Moskva, Geodezizdat, 1961. 72 p. (Moscow. Tsentral'nyy nauchno-issledovatel'skiy institut geodezii, aerofotos"yemki i kartografii. Trudy, no. 143, 1961). QB275 N6u
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 8, 1962, 8G 260. QB1.A17553

Work carried out in 1954-1959 at the Central Scientific Research Institute of Geodesy, Aerial Photography and Cartography in the preparation and investigation of photographic and photoelectronic equipment for geodetic instruments is described. Chapter I gives a short review of the use of photorecording in geodetic instruments and discusses the parameters of the optical systems of instruments used for mapping purposes and the requirements of photographic materials. The investigations showed that the film "Mikrat-200" must have a resolution of 200 to 250 lines per millimeter, a sensitivity of the order of 20 to 30 units, and an insignificant amount of graininess (in addition to the required antiaureole emulsion). The design features of the equipment used to record photographically the rod reading during leveling are described. Also described are those used in photorecording the positions of targets and the positions of the alidades of the horizontal circles of theodolites developed at the Institute as compared with those manufactured by other organizations. Photorecording precise levels are constructed in two models on the basis of the НПГ or НБ-2 levels, built at Aerogeopribor, and the ФЭД camera. In the first model, in addition to the visual observations, the positions of the r o d a n d the graticle are photographed; in the second model, the position of the bubble of the contact level is also photographed. Results of the investigations were determined from a photogram for which a large instrument microscope was used to make the measurements. The accuracy of the measurements from the photogram for a single pointing on the image of the rod divisions is characterized by a mean square error of $\pm$ 3 m, and with 10 setups, $\pm$ 1 m, which corresponds to the error of reading the rod of 0.075 mm. The mean square error in relative elevation (line of sight of 50 m) in photorecording the bubble of the level and of the rod turned out to be 0.11 to 0.15 mm. The investigations showed that the exposure time for existing photographic materials is still rather long and changes with illumination. This circumstance produces difficulties in the practical application of photorecording in leveling operations. The theodolite, in which the positions of the target and the alidade are photorecorded, was constructed on the basis of the TT 2/6 theodolite and was fitted out with two ФЭД cameras. The system for photographing a target has the following indices: equivalent focal length of the objective of the telescope, 1200 mm; diameter of the aperture of the objective, 60 mm; magnification of the auxiliary optical system, x2; size of frame, 12 x 36 mm. The system for photographing the horizontal circle gives a joint image of the circle graduations, 180° apart, in a position similar to that in optical theodolites. The magnification of the system is x5.3.

A number of observations made with this theodolite are described and the results of the tests are given. In the laboratory, the mean square error of measuring angles amounted to $\pm 1''.33$, and in the field to $\pm 1''.37$. The accuracy of photorecording the position of the axis of the theodolite's telescope is characterized by a mean square error of 0.3 to $0''.4$ over distances of 2 to 10 km. Exposure time varied from 0.5 to 2 sec. It is pointed out that the accuracy of photorecording in triangulation depends to a considerable degree on the photographic materials used. Results of investigations made with the aid of photorecording relative to personal errors of observers in pointing the target on the bisectrix of the graticle are cited. The mean value for coincidence of target relative to the center crosshair of the bisector as determined by three observers amounted to $+ 3''.5$, $+ 0''.9$, and $+ 2''.0$.

Chapter II reviews the applications of photoelectronic apparatus in geodesy, and provides a discussion of the principal circuits of these instruments and the light flux and photocurrents at the output of the photoelectric multiplier. A model of the photoelectric apparatus, constructed by the Institute on the basis of the TT 2/6 theodolite, for use in pointing on a target, is described. The diameter of the objective aperture of the sighting telescope is 60 mm with a ring-shaped entrance pupil (inner diameter, 21 mm) and an objective having a focal length of 600 mm. The light-separation unit consists of two glued prisms on the edges of which a mirror coating has been applied. Either a photoelectric or visual pointing can be made depending on the position of the prism unit. The ФЭУ-20 photoelectronic multiplers are used as photoelectric receivers. The electronic part of the equipment consists of two units -- the first contains the photomultiplier and the first stage amplifiers in a 6Ж1Б tube, and the second contains the balance resonance amplifier and the output stage of the amplifier. An electronic oscillograph or a telephone receiver is used as an indicator. The light source is a K-19 bulb (6 v, 30 w), installed in the focus of the reflecting spherical mirror in which the aperture diameter is 150 mm and the focal length is 360 mm. The light flux is modulated with a frequency of 280 kilocycles by a mechanical modulator produced by a ДГ-4 motor. The light source and the electric motor are powered by a storage battery. When the distance between the light source and the instrument is 20 km and when the direction to the target changes by $0''.1$, the variation in the light falling on the cathode of the photomultiplier amounts to 10^{-9} to 10^{-10} lumen. A model of a target was made in the laboratory from a collimator (f -- 250 mm, diameter of objective -- 40 mm), in the focal plane of which were installed circular diaphragms with aperture diameters of 10 and 25 μ, and rectangular diaphragms having dimensions of 20 x 100 μ. The values of the light sources were 1.8×10^{-9}, 1.1×10^{-8}, and 3.4×10^{-8} lumen, respectively. In pointing at a diaphragm-type target which had a diameter of 25 μ, the mean square error was approximately $\pm 0''.3$, and on the rectangular

diaphragm, $\pm 0''.2$. The investigation of the dependence between errors of pointing and the values of the light source demonstrated that when there is a sixfold reduction of light from the target, the mean square error of pointing is increased by a factor of three or four. When the indicator is auditory (during the pointing at the target the acoustical tone of the signal disappears) the mean square error of the pointing as related to the shape of the image of the target is found to be within the limits of ± 0.29 to $\pm 0''.65$. When the observations are visual the mean square error is ± 1.2 to $\pm 1''.4$. It was concluded that the mean value in direction (from 10 setups) is determined with a mean square error of $\pm 0''.1$; personal errors of the observers apparently had no effect on the results. Field tests of the photoelectric apparatus were run in 1958 under unfavorable meteorological conditions. At distances of 2.0 and 6.2 km the mean square error in direction (in one setup) amounted to ± 0.7 to $\pm 0''.9$. In the subsequent laboratory investigations it became clear that the reasons for the lower accuracy for the field measurements was the poor adjustment of the prisms of the optical assemblage.

Chapter III discusses the possibility of increasing the accuracy and sensitivity of the photoelectric equipment. It is pointed out that the methods of storage, filtration, synchronous storage, and correlation of reception can be used to distinguish between noise (when present) and the signal. There is a short discussion of each of these methods. A new photoelectric circuit is described in which improved filtration is achieved by introducing a crystal circuit and a second resonance circuit into the signal potential circuit. An integrating circuit with a constant time of two seconds is connected in front of the microammeter. A voltage divider is introduced into the circuit to control the transmitted signals. A phase-sensitive detector was made of semiconductor diodes. The mean square error of one pointing using the microammeter was within the range of ± 0.12 to $\pm 0''19$.

GEODETIC INSTRUMENTS

A. Astronomic Universals

The АУ 2/10 astronomic universal is the instrument currently most widely used in the Soviet Union for making observations of Laplace stations, the end stations of base lines, and the astronomically determined positions of independent geodetic networks and stations. The book cited below contains a chapter describing this instrument in detail (including photographs and diagrams). The following review of this chapter contains brief descriptions of some of the mechanical features and components of the optical systems of the telescopes, eyepieces, and microscopes abstracted from this source.

1. Grishin, B. S. The АУ 2/10 astronomic universal instrument. IN HIS: Yustirovka geodezicheskikh in...rumentov (Adjustment of geodetic instruments). Moskva, Geodezizdat, 1962. 99-104.
TA562.G7

General Description

- Horizontal circle
  - 2 microscope micrometers: graduations of drum, 2"
- Vertical circle
  - 2 microscopes with 10" verniers
  - Diameter of graduated circle, 135 mm; smallest division, 5', read clockwise
- Main telescope, central, broken, external focus
  - 2-lens objective
  - Prism
  - Pivoting eyepiece micrometer with two interchangeable eyepieces, rotation 90°
- Reading telescope, straight
  - 2-lens objective
  - Eyepiece equipped with micrometer (same specifications as those of the TT 2/6 theodolite)
- Levels:
  - Striding level: graduations, 2 -- 2".5 per 2 mm
  - Talcott level: graduations, 1.2 -- 1".4 (on main telescope)
  - Level of alidade of vertical circle: graduations, 6 -- 10"
- Weight of instrument, 35 kg; 71 kg including case

The optical systems of the АУ 2/10 are those of the main telescope, the microscopes of the horizontal and vertical circles, and the reading telescope.

Optical System of the Main Telescope

2-lens objective	
Prism	
Eyepiece (graticle and eyepiece, with micrometer screw)	
Diameter of objective aperture	55 mm
Resolution of objective	2".56
Focal length of objective	450 mm
Focal length of eyepieces	10 mm and 8 mm
Overall magnifications	x45 and x56

Diameter of exit pupil	1.2 and 1.0 mm
Angle of field of view	0°54'
Focusing limits	5 mm to ∞
Distance of exit pupil	2.76 and 1.4 mm
Graticle (spider web): 9 fixed hairs and a movable bisector and wire	
Angular distance between wires	90"
Width of bisector	30"
Distance between bisector and the wires parallel to it	115"
Drum of eyepiece micrometer	100 divisions
Value of graduations of drum	1"
Eyepieces of micrometer, together with graticle, rotatable by	90°
Angle of rotation set according to position of circle, graduations	90° sector 1°
Maximum tilt of telescope with striding level attached	73°

The optical systems of the horizontal circle and the reading telescope are similar to the microscopes of the horizontal circle and the reading telescope of the TT 2/6 theodolite (see page 11 of this report).

The optical system of the microscope of the vertical circle consists of an objective, prism, scales, and an eyepiece. The magnification of the microscope is x28; focal length of the objective, 30 mm; and the focal length of the eyepiece, 13.5 mm. The field of view of the microscope (visible distance on the circle) is 4 mm, which corresponds to 3° 10' on the circle; the distance of the exit pupil is 6.3 mm. The vernier scale of the microscope is divided into 30 parts corresponding to 29 graduations of the circle.

The following source is representative of the results of a recent test on a new attachment for the AY 2/10 carried out by the staff of one of the leading geodetic institutes in the Soviet Union.

2. Kuznetsov, A. N. Longitude determination with the AY 2/10 universal astronomic instrument in which star passages are photoelectrically recorded. IN: Moscow. Moskovskiy institut inzhenerov geodezii, aerofotos"yemki i kartografii. Trudy, no. 48, 1961, 149-154. QB275.M63, no. 48
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 9, 1962, 9G 49. QB1.A17553

The N. A. Belyayev photoelectric attachment for the AY 2/10 astronomic-universal instrument is produced in the Experimental Workshop of the Moscow Institute of Engineers of Geodesy, Aerial Photography and Cartography. This instrument consists of a device to record star passages photoelectrically by a radio receiver-amplifier, and an undulator with a device to determine the delay of the photoelectric device. The results of longitude determinations made with this equipment at the Institut pavilion are given. The mean square error in the determination of time from one pair of stars was ± $0^s.043$. The mean square errors in longitudes with unit

weights determined from the inner convergence of longitudes, and from clock corrections, were $\pm 0^s.016$ and $\pm 0^s.018$, respectively. The difference between the assumed and the derived value for the longitude of the pillar of the pavilion was $\Delta\lambda = -0^s.005$. The results of the observations showed that there were no noticeable systematic errors and the instrument was very accurate.

B. Theodolites

High-Precision Soviet Instruments

3. Grishin, B. S. The TT 2/6 triangulation theodolite. IN HIS: Yustirovka geodezicheskikh instrumentov (Adjustment of geodetic instruments). Moskva, Geodezizdat, 1962. 85-99.
TA562.G7

The TT 2/6 theodolite is a high-precision geodetic instrument designed to measure horizontal angles and zenith distances at first-order triangulation stations.

The readings of the horizontal circle are made with the aid of two microscope-micrometers having drum graduations of 2", and with a scaled microscope with estimations to 6". The principal telescope is astronomic, straight, and central, with internal focusing, and consists of a 2-lens objective, eyepiece micrometer, and two interchangeable eyepieces. The reading telescope is astronomic, straight, and consists of a 2-lens objective and an eyepiece equipped with a micrometer. The weight of the instrument is 27 kg; with packing case and canvas cover, 63 kg.

The TT 2/6 theodolite consists of four main parts: 1) a lower part, including a tribrach with the horizontal circle and the vertical axis and plate supporting two microscope-micrometers as well as the mount for the reading telescope; 2) an upper part, including the main telescope, horizontal axis, and the vertical sector with the scale microscope; 3) the striding level; and 4) the reading telescope.

The optical system of the theodolite consists of a main telescope, circle microscopes, a microscope of the vertical sector, and a reading telescope. The optical system of the main telescope consists of a 2-lens objective and an eyepiece. The graticle and eyepiece are controlled by the micrometer screw.

Basic Characteristics of the Main Telescope

Diameter of the free aperture of the objective	65 mm
Resolution of the objective	2".15
Focal length of the objective	520 mm
Focal length of the eyepieces	10 and 8 mm
Overall magnification	x52 and x65
Diameter of the exit pupil	1.25 and 1 mm
Angle of field of view	0°43' and 0°37'
Limits of focusing	5 to ∞
Distance of exit pupil	4 and 3.2 mm
Spider-web graticle	
Three horizontal wires	
Movable vertical bisector	
Angular distance between wires	8'35"
Width of bisector	30"
Drum of the eyepiece micrometer is subdivided into	100 parts
with graduations of	1"

The optical system of the microscope of the circle consists of the objective of the microscope, displacement prisms, and the eyepiece. The graticle and eyepiece are controlled by the micrometer screw.

Principal characteristics of the Microscope-Micrometer of the Vertical Circle

Magnification	x49
Focal length of the objective	28.2 mm
Focal length of the eyepiece	20 mm
Field of view of microscopes	3.1 mm
which, on the circle, corresponds to	1°37'
Distance of the exit pupil	9.56 mm
Drum of the micrometer is divided into	60 parts
2.5 turns of the screw corresponding to the displacement of the bisector wire in one graduation of the circle	
Value of one graduation of the micrometer drum	2"
Bisector: two pairs of spider-web wires	
Distance between axes of the bisectors	4'
Width of bisectors	53"
Fine adjustment screw of the micrometer has a run of	0.25 mm

The optical system of the microscope of the vertical sector consists of the objective, scales, and eyepiece.

Principal Characteristics of the Microscope of the Vertical Sector

Magnification of microscope	x48
Focal length of the objective	15.6 mm
Focal length of the eyepiece	10 mm
Field of view of the microscope	3 mm
corresponding, on the circle, to	2°9'
Distance of the exit pupil	4.3 mm
Scale of the microscope is divided into	100 parts
Ten divisions of the scale correspond to one division of the sector	

The optical system of the reading microscope consists of a 2-lens objective and an eyepiece. The graticle and the eyepiece are controlled by the micrometer screw.

Principal Characteristics of the Reading Telescope

Diameter of the free aperture of the objective	36 mm
Resolution	4"
Focal length of the objective	360 mm
Focal length of the eyepiece	12 mm
Overall magnification	x30
Diameter of exit pupil	1.2 mm
Angle of field of view	1°
Limits of focusing	7 m to ∞
Distance of exit pupil	8 mm
Spider-web graticle:	
Two horizontal wires	
Movable vertical bisector	
Angular distance between wires	150"
Width of bisector	35"
Drum of the eyepiece micrometer is subdivided into	100 parts
Value of drum divisions	1".4

4. Grishin, B. S. The ThB optical theodolite. IN HIS: Vysokotochnyye opticheskiye teodolity (High-precision optical theodolites). 2d ed., rev. Moskva, Geodezizdat, 1959. 90-129.
TA575.G74

The ThB theodolite is a light-weight, easy-to-operate, high-precision geodetic instrument. Horizontal- and vertical-circle images are read with the aid of the optical systems of the microscope objectives in a single field of view of the reading microscope whose eyepiece is aligned with the eyepiece of the telescope. Circle readings are made with the aid of a single eyepiece micrometer with 1" values for the scale divisions. Tenths of seconds are estimated by eye. The reading telescope is straight, astronomical, and internally focused. The horizontal and vertical circles are made of optical glass and the instrument is equipped with electric illumination. The theodolite weighs 10.5 kg; the case (together with attachments), 7 kg; the tripod, 9 kg; and the centering plate, 4.5 kg. The optical plummet has a magnification of x1.25, a field of view of 8°, and a viewing distance of from 0.2 to 7.2 m.

The optical system of the ThB theodolite consists of the following: optical system of the telescope, optical system of the objective of the microscope of the horizontal circle, optical system of the objective of the microscope of the vertical circle, optical system of the micrometer, optical system of the reading microscope, the optical plummet, and the horizontal and vertical circles.

The optical system of the telescope consists of a complex objective, the "graticle", and two interchangeable eyepieces. The basic characteristics of the telescope are: magnifications of telescope, x34 and x48; angle of field of view, 1°14' and 0°52'30"; focal length of objective, 259 mm; equivalent focal length of objective, 381 mm; diameter of the aperture of the objective, 60 mm; limit of focus, 10 m to ∞ ; focal length of eyepiece, 11.25 mm and 8 mm; magnifications of eyepiece, x22 and x31; field of view of the eyepiece, 39° and 40°; and diameter of the exit pupil, 1.75 mm and 1.25 mm.

The objective of the telescope consists of the objective itself and a focusing lens (component of two lenses). The graticle consists of two cemented plane-parallel plates, one of which contains the cross-hairs. The interchangeable eyepieces are orthoscopic and consist of a cemented, three-lens collective and an eyepiece. The graticle can be rotated horizontally and vertically.

The optical system of the eyepiece of the micrometer of the horizontal circle consists of an illuminating prism with a condenser, alidade prisms with a transmitting system of lenses, inverting prisms, and an objective with x3.05 magnification.

The optical system of the objective of the vertical-circle microscope consists of an illumination prism with condenser, an alidade prism with a transmitting system of lenses, a unit of prisms, an objective with a magnification of x3.82, prisms, collective, and inverting prisms.

The horizontal and vertical circles are illuminated with the aid of mirrors. The illumination system consists of electric bulbs and condensers. Light falling from the bulbs on the metallic mirror illuminates the cross-hairs of the telescope.

The optical system of the micrometer is so constructed that the images of the graduations of the horizontal and vertical circles, as well as of the scale graduations and index of the micrometer, are in a single plane and can be read through the reading microscope.

The optical system of the micrometer consists of immovable wedges, a unit of analyzer prisms, micrometer scales, and plane-parallel plates with a diaphragm.

The reading microscope consists of a collective, the prisms of the reading microscope, the objective, and the eyepiece. The microscope is common to the optical systems of the microscope objectives of the horizontal and vertical circles, since both objectives are focused in a single plane which passes through the line of separation of the unit of analyzing prisms and perpendicular to the axis of the collective of the reading microscope. The magnification of the reading microscope is x16.6, and the overall magnification of the microscopes of the horizontal circle is x50.5, and that of the vertical circle is x63.5. The field of view of the reading microscope of the horizontal and vertical circles is 2° (in divisions of the circle).

The optical plummet consists of prisms, an objective, and an eyepiece. The graticle is attached to the first lens of the eyepiece.

The horizontal and vertical circles of the ThB are made of optical glass. The diameter of the circle on which the divisions are imprinted is 125 $\pm$ 0.05 mm for the horizontal circle, and 100 $\pm$ 0.05 mm for the vertical circle. The total error of the diameters of the horizontal circle does not exceed $\pm$ 2"; the smallest division of the circles is 20' (if the circle is divided into 400 grads, the smallest division is 20^c); the thickness of the graduations of the circle is 0.01 $\pm$ 0.002 mm. The tolerance for eccentricity of circle divisions to the center aperture of the circle is of the order of 0.1 mm, and does not exceed 20" for non-parallelism in the flat surfaces of the circles.

The scale of the eyepiece micrometer is designed so that a displacement of 10' of the image of the circle graduations corresponds to shifting the scale 600 divisions in the field of view of the reading microscope (length of scale, 55 mm). If the circles are divided into 360°, the scale is subdivided into 600 divisions, the value of a scale division being 1', and if the circle is subdivided into 400^g, the scale is subdivided into 1000 divisions, with the value of one division being 1^{cc}.

The eyepiece micrometer is designed for reading the horizontal and vertical circles. The circles are subdivided every 20'. The micrometer scale has 600 divisions of 1" each. When shifting the scale, each division corresponds to 10' at all distances.

5. Grishin, B. S. The OT-02 theodolite. IN HIS: Vysokotochnyye opticheskiye teodolity (High-precision optical theodolites). 2d ed., rev. Moskva, Geodezizdat, 1959. 7-21.
TA575.G74

The OT-02 theodolite is small, hermetically sealed, light weight, and easy to use in making observations in rough terrain. It is built by the "Aerogeoinstrument" Plant and is designed for high-order triangulation work. Third-class astronomic determinations also can be made with this instrument.

The horizontal and vertical circles are made of glass; the optical systems of the microscopes of the horizontal and vertical circles transmit the inverted images of the graduations of the circles into the field of view of the reading microscope; and, instead of several microscope-micrometers, there is one eyepiece micrometer.

The distinguishing feature of this theodolite is that the images of the graduations of the horizontal and vertical circles are viewed with the aid of the optical systems of the objectives of the microscopes of the horizontal and vertical circles in one

field of view of the reading microscope, the eyepiece of which is located in line with the eyepiece of the telescope. The readings are made with the aid of one eyepiece micrometer, the graduations of the second disk being 0".2. The telescope is astronomic, straight, central, and internally focused. The instrument assures normal operations at temperatures ranging from -25° to +50°C. It is electrically illuminated.

The packing case is 233 mm in diameter and 420 mm high; the weight of the instrument, without centering plate, is 10.8 kg and with it, 14.8 kg. The tripod weighs 8 kg, and the centering plate 4.18 kg.

Two levels are mounted on the instrument: 1) the level of the alidade of the horizontal circle, which is used to rotate the instrument's axis to the plumb position; and 2) the centering level, which is operated by a tangent screw on the side of the vertical circle. The value of a division of the level is 6 to 7" per 2 mm. The level of the alidade of the vertical circle is connected with the centering level. The value of a division of the level is 10 to 12" per 2 mm.

The optical system of the telescope consists of an objective, the "graticle," and one of three interchangeable eyepieces. Its basic characteristics are: length of telescope, 265 mm; magnification of telescope, x24, x30, and x40; angle of field of view, 1°40', 1°20', and 1°; diameter of exit pupil, 2.5 mm, 2.0 mm, and 1.5 mm; equivalent focal length of objective, ≈ 350 mm; diameter of the aperture of objective, 60 mm; resolving power of objective, 2".4; angular distance of bisector of wire, 35"; and the focusing limit, from 5 m to ∞. The objective consists of the objective itself (3 lenses) and a two-lens focusing component. The graticle consists of two plane-parallel plates, on one of which the cross-hairs are affixed, and on the other the diaphragm. The interchangeable eyepieces are symmetrical and consist of four lenses. The focal lengths of the eyepieces are 14.6 mm, 11.7 mm, and 8.6 mm.

The optical system of the objective of the microscope of the horizontal circle consists of the illumination system, the alidade prisms, an objective with fourfold magnification, and interchangeable prisms. In the illuminating system, the prism, condenser, and alidade prisms for both sides of the circle are so constructed that the graduations of the circle are illuminated and their images transmitted simultaneously through the objective of the microscope of the horizontal circle. The horizontal and vertical circles are illuminated, rotated, and tilted with the illuminated mirror or condenser. The second disk of the eyepiece micrometer is illuminated simultaneously with the circles.

The optical system of the objective of the microscope of the vertical circle consists of the illumination system, the alidade prisms, an objective with a threefold magnification, an interchangeable prism, cover glass, and inverting prism.

The illuminating system of the vertical circle consists of prisms, a condenser, and alidade prisms. Their construction provides for the simultaneous illumination of the circle graduations and the transmission of their images through the first component of the objective of the microscope of the vertical circle. Prisms have been inserted in the transmission system which transmit light to a metal mirror thereby illuminating the graticle.

The optical system of the micrometer is constructed to reduce the images of the graduations of the horizontal and vertical circles, as well as the images of the graduations of the second disk and index micrometer, to a single plane in which they are viewed through the reading microscope. The illumination system consists of plane-parallel plates, analyzer unit, prisms, inverters of the images of circle graduations, the second disk, and illuminating prisms.

The reading microscope consists of a collective, prisms, an objective, and an eyepiece. The reading microscope is common to the optical systems of the objectives of the microscopes of the horizontal and vertical circles since both objectives give an image in the plane of the analyzer unit. The magnification of the reading microscope is x9.3 and the overall magnification of the microscope for the horizontal circle is x37, and for the vertical circle x28. The field of view of the reading microscope is 8 mm x 3.8 mm, which corresponds to $1°40'$ on the horizontal circle and to $3°20'$ on the vertical circle.

The exit pupil of the microscope is 25.5 mm from the horizontal circle and 25.0 mm from the vertical circle. The diameter of the exit pupil is 1.7 mm for the microscope of the horizontal circle and 1.6 mm for the microscope of the vertical circle.

The horizontal and vertical circles of the OT-02 theodolite are fabricated from BK-10 optical glass. The tolerance "on the wedge" of the horizontal circle is 2", and its flat surfaces are characterized by the values $\Delta N = 0.3$ and $N = 1$. The diameter of the circle on which the graduations are imprinted is 135 mm for the horizontal circle, and 90 mm for the vertical circle. The smallest division on the horizontal circle is 4', and 8' for the vertical circle. The thickness of the graduations is from 6 to 7 μ on the horizontal circle and from 7 to 8 μ on the vertical circle. The total error in the diameter must not be more than $\pm$ 1".5 in the horizontal circle and not more than $\pm$ 2".5 in the vertical circle.

The second disk is made of optical glass 22 mm in diameter and 2 mm thick. The diameter of the circle on which the graduations denoting the inner ends of the graduations of the second disk are represented is 20 mm. In the disk there is an opening for the axis of the cam which is 8 mm in diameter. The arc of the disk has been graduated for 350° [sic], and subdivided into 600 parts with values inscribed every 10 divisions from 1, 2, 3, to 60. In addition, on both sides of the working area of the disk there are 4 graduations. The width of the graduations of the second disk is 0.01 $\pm$ 0.002 mm.

The eyepiece micrometer is used to make the readings of the horizontal and vertical circles. The horizontal circles are subdivided into 4' divisions. The disk of the second micrometer has 600 divisions whereby one turn of the second disk corresponds to 2'. Consequently, the value of a division on the second disk equals 0".2.

Medium-Accuracy Soviet Instruments

6. Blyumin, M. A. The TT-4 theodolite. Geodeziya i kartografiya, no. 3, 1962, 25-32. QB275.G45

The TT-4 is a medium-accuracy optical instrument designed to measure horizontal and vertical angles, to determine astronomic and magnetic azimuths, and to measure distances with a cross-haired range finder. It is a repeating-type instrument. One of its basic features is that readings are made only on one side of the circle with an optical system. The images of the horizontal and vertical circles and of the scale of the eyepiece micrometer are viewed simultaneously in the field of view of the reading microscope. The eyepiece of the reading microscope is set in line with the eyepiece of the telescope.

The instrument has glass circles, is equipped with a compass of the oriented type, has an eyepiece shade for observing tall targets, is centered optically, and is electrically illuminated. Circle readings are made by setting the closest graduation in the bisector of the microscope (degrees and thirds of degrees) and the index of the eyepiece micrometer (minutes less than 20, and seconds).

The mean square error of the horizontal circle is $m_o = \pm 2".3$; that of the vertical circle is $\pm$ 2".6. The dead rate of the eyepiece micrometer is +2".3. The run of the microscope is +6".9 for the horizontal circle and +7".4 for the vertical circle.

The TT-4 has no vertical-circle alidade in the true sense of the word. The reading line is horizontalized with respect to the tilt of the microscope, since the set screw of the vertical circle is directly connected with the microscope mounting.

Field tests on nine TT-4 theodolites compared in part with results obtained with an OT-02 theodolite:

1. The reading device of the instrument is very precise. This leaves the necessity of building the TT-4 with a repeater open to question since the use of the repetition method with a sufficiently accurate reading system is unsuitable. The high precision of the reading device ($\pm 2''$) does not correspond to the accuracy of the theodolite ($\pm 8''$). With the TT-4, a reading device of the scaled-microscope type would be advantageous since it would simplify its design considerably.

2. There is no need to maintain the usual tolerances for variation in the double collimation error in one setup when measuring horizontal distances with the TT-4. The collimation error is obtained as the difference between two single readings, and the variation in eccentricity, which amounts to $2(f_a + f_c)$, is always added to the change in value 2c. A variation in the 2c value within 2' should be considered normal.

3. Polygonometric-traverse angles should be measured as follows to offset the effect of free play in the vertical axis: measure the angle directly in the first half-set, and its complement, to 360°, in the second. In both half-sets the alidade should be rotated in one direction only. Then the alidade is rotated in the opposite direction. An accuracy of 1:1000 can not be maintained in measuring theodolite traverses.

4. The quality of the image for short distances was good. For t[illegible] 10 [illegible], a clear image was difficult to obtain (only 4 of the 9 theodolites gave clear images). This is considered one of the fundamental drawbacks of this instrument.

5. In centering the bubble of the level of the vertical circle, the screw always must be turned in one direction.

6. In order to offset the effect of the eccentricity of the alidade and circle on the accuracy of the measurements, horizontal angles should be determined for two positions of the circle.

7. The TT-4 is not adaptable for working from geodetic towers. For this purpose a nonmetallic metal plate will have to be designed as accessory equipment.

8. The adjustment nuts of the tangent screws loosen spontaneously and the screws begin to wobble in both sockets. Therefore, a special locking device must be installed.

9. The TT-4 is prized by field men who believe that it can completely replace the TT-50 and the TT-5. The TT-4 measures angles more accurately and is easier to operate. It can be used to determine the coordinates of intersected and resected stations at distances of from 3 to 10 km. Its optical quality, however, needs improvement.

7. Dudin, A. F. A theodolite. Author's Certificate No. 129831, class 42 s, 5/01. Bulleten' izobreteniy, no. 1, 1960.
   ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 3, 1961, 3G 265P. QB1.A17553

A theodolite is described which has a hollow, conical, vertical axis. This design permits pointing the telescope at any angle of inclination. Steep inclines can be surveyed without introducing corrections for direction and angles. The telescope of the theodolite is removable and can be reassembled in camp.

Low- to Medium-Accuracy Hungarian Instruments

8. Halmos, Ferenc. Determination of the principal characteristics of the MOM Te-D1 tachymeter theodolite. Geodézia és kartografia, v. 14, no. 1, 1962, 12-21. TA501.G38
   ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 7, 1962, 7G 234. QB1.A17553

The MOM Te-D1 tachymeter theodolite is manufactured by the Hungarian People's Establishment of Optical Instruments and has the following characteristics: mean square error (mse) in reading the horizontal circle using the eyepiece micrometer, $\pm 9.7^{cc}$ ($\pm 3''.3$); mse when pointing, $\pm 7.3^{cc}$ ($\pm 2''.4$); mse when measuring direction in one setup, $\pm 16.6^{cc}$ ($\pm 5''.4$); maximum eccentricity of the horizontal circle, $\pm 20.8^{cc}$ ($\pm 6''.4$), and of the vertical circle $+ 28.9^{cc}$ ($9''.6$); accuracy of distance measured with the special stadia rod supplied with the instrument, ± 5 to ± 8 cm/100 m; centering accuracy of the instrument, 0.1 mm; and the mse of an angle measured with two positions of the telescope at stations of polygonometric traverse, $\pm 24^{cc}$ ($\pm 8''$).

9. Halmos, Ferenc. Investigation of the errors of the circle graduations of low- and medium-accuracy theodolites. Acta technica akademiae scientiarum hungaricae, v. 37, no. 1-2, 1961, 23-45. T4.M323
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 8, 1962, 8G 258. QB1.A17553

Various methods of inscribing graduations on circles are described, with emphasis on the photographic method used in the preparation of the glass circles for the theodolites manufactured by the Hungarian MOM Optical Establishment. The causes of errors in circle graduations inscribed by the photographic method are discussed. The author considers the principal causes for error to be uneven shrinkage of the photoemulsion (causing errors of up to 2"), errors in the graduation of the model circle, imperfections in polishing the circle of the model and the circle being graduated, noncoincidence of centers of rotation of the circles, and deformation of the circle caused by "ageing" (to lessen glass deformation, glass is artificially aged). The investigations of the errors of the circle graduations of the MOM Te-D1 theodolites are described.

In order to make the investigation more precise, the usual micrometers of these theodolites (reading accuracy, 6") were replaced by micrometers whose reading accuracies were 1". The mean square error in the measurement of an angle in one setup computed from 300 observations using the Te-D1 theodolite with the new micrometers amounted to ± 1".5. The errors in the diameters of the circles were tested by the Heuvelink method. The Fourier series was used to process the results of the observations (retaining four terms). Formulas used to compute the coefficients of the Fourier series and to evaluate the accuracy of the results obtained are given. The values of the coefficients were determined from nomograms. In one Te-D1 theodolite, the mean square value of the error of the diameter amounted to ± 1".5, and the mean square accidental error of the graduations amounted to ± 0".7; in another model these errors were ± 0".8 and ± 0".2, respectively. These errors are entirely acceptable for medium-accuracy theodolites. To investigate the circle graduations of the Gamma TeE theodolite (reading accuracy, 30"), a special attachment was used which made the direct measurement of the angle between circle graduations possible. The measurements were made every 10° for the entire circle. Each angle was measured five times. The deviation from the mean of the five measurements varied within the limits of ± 0".6 to ± 1".4. The mean square accidental error in the graduations of the Te-E circles amounted to ± 1".6.

10. The Te-Cl universal theodolite. Feingerätetechnik, v. 10, no. 7, 1961, 334. Q184.F37
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 10, 1961, 10G 229. QB1.A17553

Principal technical data are presented for the Hungarian MOM Te-Cl theodolite. The magnification of the telescope is x30; the field of view is 1°20'; the intercept of the range finder is 100; the shortest pointing distance is 2 m; and the magnification of the reading microscope is x24. The theodolite circles are made of glass and are graduated every 20'. The eyepiece micrometer is graduated every 10" and has a reading accuracy of 1". The accuracy of the coincidence of the end of the level bubble is 1". The weight of the instrument is 5.3 kg.

11. The small Te-E4 theodolite. Feingerätetechnik, v. 10, no. 7, 1961, 334. Q184.F37
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 10, 1961, 10G 230. QB1.A17553

Principal technical data are provided for the small Hungarian MOM Te-E4 theodolite designed for construction and exploratory operations. The magnification of the telescope is x16; the diameter of the free aperture of the objective is 25 mm; the stadia intercept is 100; the shortest pointing distance is 1.5 m; both circles are graduated every 5'; and the reading accuracy is 30". The sensitivity of the circular level is 5', and the sensitivity of the cylindrical level on the vertical circle is 30" (per 2 mm). The instrument fits into a metal case. The dimensions of the instrument are 136x146x192 mm. The weight of the instrument including the case is 4.5 kg.

East German Theodolite

12. The small Theo 120 theodolite of the Zeiss People's Establishment. Fluchtstab, 1961, v. 12, no. 5-6, 66-68.
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 11, 1961. 11G 272. QB1.A17553

The German Democratic Republic has issued a Theo 120 theodolite. The instrument's reading microscope, which simultaneously produces the image of both circles, is located on the side of the telescope stand and can be set in any position convenient for operation. The horizontal circle can by connected to the alidade with a clamp, which transforms the instrument into a repeating

theodolite. The instrument is centered by means of its telescope, set in a vertical position. The telescope's magnification is x16, its objective aperture is 32 mm, its field of view is 2°6', its length is 125 mm, and its shortest sighting distance is 0.9 m. A reversible level with a division value of 2'/2 mm is attached to the telescope. The range-finder graticle with stadia intercepts of 50 and 100 is arranged for observations on horizontal and vertical rods. The graticle has an additional circle for azimuthal observations of the sun. The circles are made of glass, 62 mm in diameter; their smallest division is 10^c (or 10'). Estimations of the index are to 1^c (or 1'). The microscope's magnification is x19. The instrument is packed in a metal case and weighs 2.8 kg. The mean square error of a direction measured (using one setup) is $\pm$ 20".

C. Range Finders

13. Zelener, V. S., and K. A. Babloyants. Experience in the use of the ДДЗ range finder. Geodeziya i kartografiya, no. 11, 1962, 38-40. QB275.G45

The ДДЗ (Differentsial'nyy Dal'nomer 3) differential optical range finder was found adequate to provide horizontal control for engineering operations at a scale of 1:1000. The instrument was field tested for three years at the Rostov Branch of the All-Union State Institute for the Design and Planning of Electrical Equipment for Heat Engineering Installations (Teploelektroproyekt) where it was used to measure horizontal control lines and to determine the coordinates of the corners of structure foundations.

During an engineering survey undertaken in 1960-1961 to provide 1:1000 plans for a heat and power station and a 1:500 plan for an underground utility area, 61 lines were measured exclusively with the ДДЗ attachment. A total of 1517 instrument-to-rod measurements were made from 65 stations; 76 of these were made with an ordinary tape and 1441 with the ДДЗ optical range finder. The ДДЗ reduced the number of theodolite traverses in the network, since the mean vector length of the ДДЗ is approximately 60 m and that of a tape is 20 m; the total length of theodolite traverses plotted was 4 km. Had a tape been used, 9 to 10 km of theodolite traverses would have been necessary. Measurements with the ДДЗ are made to the second, rather than the fourth, order of difficulty; measurements can be made after a heavy rain when terrain conditions prevent the use of the tape. The cost of operations is reduced almost three times.

It is recommended that the following conditions be observed in using the ДДЗ range finder:

1. A special base should be established for checking an instrument with the ДДЗ attachment. The range-finder intercept must be set at 100 to check intercept stability. The base line should be protected from the wind, and the distance between zero points on the scale (19.5 m) should be checked regularly against standard tapes. In staking the base, an odd number of unequal segments satisfy the requirements for determining the intercept for the range finder, and obviate the necessity for supplementary adjustments in the base.

2. In measuring lines with the ДДЗ using vertical rods it is necessary to determine the angle of inclination by pointing the center crosshair on the rod graduations to read off distances. A zero position of + 17' (the value algebraically assigned to each angle of inclination) is established on the vertical circle.

3. Each operator must be equipped with tables of correction values for the inclined lines.

4. For distances of less than 20 m, readings from the rod are difficult and the Instructions recommend that they be made with the usual wired range finder with the range-finder shade pulled out. However, in practice this guarantees neither accuracy nor convenience of operation. In measuring short distances it is best to use scales with centimeter divisions. Thus far the usual millimeter rule has been used by simply aligning it with the rod at the observation station. It is suggested that the rule be attached to the rod so that it can be moved along one or both of the rod's edges.

14. Beschasnyy, G. K. A range finder with an inclined wedge. IN: Sbornik statey po voprosam marksheyderskogo dela, vyp. 37 (Collection of articles on mining affairs, no. 37). Leningrad, 1959. 179-185.
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 1, 1961, 1G 283. QB1.A17553

An optical range finder developed by the author at the All-Union Scientific-Research Institute of Mining Engineering is described. Essentially, the new range finder is an attachment to the reading telescope of a theodolite. This attachment is equipped with an achromatic wedge placed in front of the objective and inclined at a certain angle to the sighting axis of the telescope. The inclined wedge, fastened in a metal ring by means of two cylindri-

cal petals, covers the central zone of the objective and forms a constant parallactic angle of 34'23". The rod of the range finder is equipped with a reversed vernier, the length of which, in accordance with the magnification of the wedge, is 1/110th part larger than the nominal. Exact coincidence of the vernier graduations with those of the rod is achieved by inclining the telescope. The first two figures read are those on the rod, the remaining three are from the vernier scale, utilizing the center crosshair of the telescope. In measuring vertical angles the upper crosshair of the graticle is pointed on the upper graduation of the displaced image of the vernier, which assures the coincidence of the sighting axis with the bisectrix of the parallactic angle. To obtain ground distance, a correction is introduced into the distance readings. In measuring 20- to 100-m distances using an experimental model of the range finder, a mean relative error of 1:3900 was obtained. It is pointed out that in comparison with the differential range finder the optical scheme and the design of the device offered here is simpler, the quality of the rod image is better because of a reduction in the magnification of the wedge, and there is greater constancy in the parallactic angle. It is not possible, however, to obtain an intercept of the order of 200 with an inclined wedge.

15. Beschasnyy, G. K. A double-image wedge range finder with a telescope micrometer. Author's Certificate No. 125897. Byulleten' izobreteniy, no. 2, 1960. T285.A32
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 4, 1961, 4G 276P. QB1.A17553

A double-image geodetic range finder designed as an attachment to the objective part of the telescope of the instrument is described. A constant parallactic angle is produced by an achromatic wedge covering one half of the objective; the second half of the objective is represented by the telescope lens which acts as an eyepiece micrometer. The wedge and the lens are housed in an overall mounting which can be tilted within small limits on ball bearings by means of screws. The body of the attachment rests on the end of the mounting of the objective at three points, assuming a constant position during repeated setups. A special feature of the proposed range finder, according to the author, is the separation of the work of the eyepiece micrometer from the function of the construction of the parallactic angle. This simplifies the computation of the optical system, facilitates the conversion of one stadia intercept to another, and increases the accuracy of the distance measurements.

16. Agroskin, A. I., and B. A. Golovatskiy. Scaled range finder. IN: Novosibirsk. Novosibirskiy institut inzhenerov geodezii, aerofotos"yemki i kartografii. Trudy, no. 14, 1961, 95-103. ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 2, 1962, 2G 226. QB1.A17553

A scaled range finder used with rods of invariable lengths is described. The range finder is designed to determine distance measurements in theodolite traverses and analytical networks laid out in accordance with the principles of linear triangulation. The distinguishing feature of the range finder is that there is a proportional scale in the focal plane of the internal-focusing telescope which is adjusted by a precise micrometer screw. A model of the scaled range finder, which utilized a TT-50 theodolite as a base, the telescope of an НТ level, the scale from the ДНБ-2 range-finder attachment, and the micrometer of the reading telescope of a 5" universal, was built at the Novosibirsk Institute of Engineers of Geodesy, Aerial Photography and Cartography. A vertical section to determine angles of inclination was attached to the range-finder telescope. The scale with the micrometer can be installed in either a horizontal or vertical position. This makes it possible to measure distances from the horizontal or vertical rods. The method of operating the range finder is described and its constants determined. Measurements of the length of a polygonometric side made with the range finder are compared with those made with invar wires. The data obtained indicate that the accuracy of distance measurements made with the range finder is not less than 1:1400. It is suggested that the accuracy of this range finder can be increased by using an eyepiece micrometer.

17. Nedesheva, L. P. Techniques of computing distances measured by range finders equipped with the ДНБ-2, ДНТ and ДНТ-2 attachments. IN: Moscow. Moskovskaya sel'skokhozyaystvennaya akademiya im. K. A. Timiryazeva. Doklady, no. 74, 1962, 365-374. S13.M5573
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 11, 1962, 11G 86. QB1.A17553

The inadequacies of the tables for computing distances measured with the ДНБ range finder attachment compiled by S. A. Angelov and A. P. Il'yin are indicated. New tables for computing distances determined with these instruments are proposed. The tables are in two parts and cover 25 pages.

The value $D_1 = 10{,}000/\beta$ is selected (β is the parallactic angle expressed in scale divisions) and multiplied with a computer by $k/10{,}000$ (k is the coefficient of the range finder). The correction $(c + \delta_t)$ is added to the value obtained (where $\delta_t = \lambda(t - t_o)\,k/\beta$, and c is the constant for the given theodolite and rod) which is selected from the second part of the tables. Discrepancies in distances computed from these tables and directly from the formula do not exceed 1 cm (examples are given).

D. Tachymeters

Soviet Tachymeters

18. Savchenko, A. Ye., and R. G. Lernerman. The TA-ЛС automatic tachymeter for strip-mine surveying. Ugol', no. 11, 1961, 44-45. TN4.U6
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 4, 1962, 4G 225. QB1.A17553

The TA-ЛС automatic tachymeter permits direct reading on a rod of the horizontal position and differences in elevation without using tachymetric tables. This instrument represents a combination of the KA-2 automatic alidade and the TT-50 theodolite-tachymeter. The column of the alidade is connected to the theodolite alidade by means of a conversion plate which is easy to prepare in a mine machine shop. Field work with this instrument in a strip mine is simplified because there is no need to read off the vertical angles. The values of the horizontal positions and elevations are determined from the rod with the aid of curves plotted on the glass of the graduated vertical circle. This represents a 20% saving in time. The tests of the experimental model of the instrument showed that the distances were determined with an error of not more than 1:700, and the elevations, with an error of not more than 1:800. The mean square error of measurement of horizontal angles is ± 1'.

East German Tachymeters

19. Richter, H. A. The BRT-006 base reduction tachymeter -- a new double-image range finder for surveying by the pole method. Vermessungstechnik, v. 8, no. 11, 1960, 325-331. TA501.V38
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 5, 1961, 5G 288. QB1.A17553

A new double-image range finder which has a constant parallactic angle, an interchangeable instrument base, and automatic distance reducer, manufactured by the Zeiss People's Establishment in Jena, is described. The principal mechanism of the range finder, its optical scheme, the reduction system, and the sources and magnitudes of instrumental errors are examined; the basic characteristics and results of field tests of the apparatus are

cited. The reading telescope is horizontal; the eyepiece is tilted 90° from the axis; the telescope has a 25-mm aperture objective; the field of view is 3^{g}, the magnification, x15, and the minimum pointing distance, 1.8 m. A stationary pentaprism is affixed to the upper half of the objective, and a movable pentaprism is affixed to the lower half. The parallactic angle is obtained by transverse displacement of the half lens which lies between the objective and the fixed pentaprism. To determine distance, the pentaprism is moved along the base rule (first by means of a slide, then with a set screw) until the two halves of the image, separated by the horizontal edge of the biprism, coincide in the field of view of the eyepiece. Distance is counted off along the rule in 0.5-mm graduations. A 300-m base rule and a 200-mm stadia intercept make it possible to determine from the mark or a vertical object distances of from 2 to 60 m. Distances up to 180 m can be measured with a short rod of constant length assembled at the point of sighting. The off-center positioning of the pentaprism relative to the objective provides mutual compensation of the effect of temperature on the deviation of both bundles of rays. Whem plunged, the instrument may be used to measure inclined distances or ground distance. The reduction of distances is accomplished by the automatic change in the parallactic angle by an additional displacement of the half lens depending on the angle of inclination of the pointing line. The mean square error in determining distances varies within the limits of 0.03 to 0.06%, depending on the targets observed. The instrument has horizontal and vertical circles with graduations of 5^{c} or 5' in a degree-circle graduation, and a reading accuracy of 50^{cc} (30"), depending on the notations used. Computations from both circles are read in the field of view of one microscope aligned with the eyepiece of the telescope. The mean square error of measured directions with two positions of the telescope is 40^{cc} (15"). Attention is drawn to the necessity of carefully determining range-finder constants under different external conditions and distances. The BRT-006 tachymeter can be used extensively for surveying in builtup areas with considerable vehicular movement as well as for various engineering and technical operations.

Polish Tachymeters

20. Dejneka, Bazyli. A tachymetric ("tachygrammetric") instrument. Polish patent, class 42 s, 8, no. 43363, 20 September 1960. IN: Referativnyy zhurnal. Astronomiya i geodeziya, no. 8, 1961, 8G 290. QB1.A17553

The instrument is designed for laying out polygonometric-base range-finder traverses and for topographic (plane tabling and tachymetric) surveys. It measures parallactic angles with an accuracy

of 1^{cc}. Horizontal distances and relative elevations are read from the scales of the horizontal and vertical rules attached to the telescope base. In tachymetric surveying the rule used to plot directions on the plane-table sheet or tracing cloth is attached to the instrument's axis of rotation. The rule is graduated for laying out horizontal distances on the map using a movable needle. The instrument is available in two models. The second differs from the first in that the optical compensator for magnifying the image of the horizontal base rod and the vertical scale is plotted on transparent plastic, and the image is transmitted to the eyepiece of the telescope.

Hungarian Tachymeters

21. Bezzegh, László. The MOM TA-D1 tachymeter with a circular diagram. Geodézia és kartografia, v. 13, no. 2, 1961, 112-115. TA501.G38
    ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 12, 1961, 12G 266. QB1.A17553

The new MOM TA-D1 reducing tachymeter manufactured by the Hungarian Optical Plant is briefly described. The special feature of the diagram of the tachymeter is that its separate lines form arcs of circles with different radii and centers.

22. Bezzegh, László, and Gyimóthy István. A reduction tachymeter with a device for rod readings in the form of circle arcs. Hungarian patent no. 145021. IN: Referativnyy zhurnal. Astronomiya i geodeziya, no. 5, 1961, 5G 304. QB1.A17553

A tachymeter-graticle design is described as consisting of arcs of circles arranged for reading reduced distances and relative elevations. A turn of the telescope by an angle α turns the graticle by an angle of 2α. The circles for determining relative elevations intersect with the initial circle in such a manner that positive relative elevations are read above and negative elevations are read below the initial circle. This arrangement of crosshairs simplifies the manufacture of the graticle and facilitates reading the rod.

E. Geodimeters and Tellurometers

23. On the application of light and radio range finders in constructing geodetic networks. Geodeziya i kartografiya, no. 3, 1963, 3-8. QB275.G45

Geodimeter- and Tellurometer-type range finders were first used in the Soviet Union in 1957 to lay out portions of the State geodetic network. During the past five years more than 20,000 km of polygonometric traverses have been measured, replacing second-, third-, and fourth-order triangulation. In 1961, links* of first-order polygonometry began to replace first-order triangulation links, and these range finders were used extensively to measure the base sides** of first- and second-order triangulation. During the last four years approximately 250 base sides have been measured with the NASM-2 (Swedish), the ЭОД-1, and the СВВ-1 (Soviet) range finders. It is anticipated that the Yederin-base apparatus will be used rarely during the next two years and will be replaced by these range finders, or improved models. These range finders were not used in the USSR to measure second-order polygonometric traverses until 1962. Preliminary data on the results of measurements are reported as being completely satisfactory. However, the results are not necessarily conclusive since particularly favorable areas were selected for measurements.

According to the most recent information available, all range finders currently in use in the USSR can be divided into four groups based on range, economy and ease of operation, and accuracy: 1) the NASM-2 (Swedish) and ЭОД-1 (Soviet) Geodimeter-type instruments; 2) the СДД and СВВ-1 (Soviet) Geodimeter-type instruments and Tellurometer-type instruments; 3) the CT-61 (Soviet) and NASM-4 (Swedish) Geodimeter-type instruments; and 4) the Geodimeter-type and Tellurometer-type instruments used for surveying and for connecting networks.

Possible variants, as defined by the Geodetic Service of the USSR, for replacing the Yederin-base apparatus with Geodimeter- and Tellurometer-type instruments in measuring components in networks of various orders applicable to the classification of geodetic networks adopted in the USSR are given in the following table. [See Appendix B for the current official criteria and standards.]

* The Russian term used here ("zveno") means a section in arc triangulation of area triangulation, as used and defined in U.S.C. and G.S. Special Publication, no. 242.

** "Base side" is the term given to a side of triangulation measured directly by a Yederin-base apparatus or a Geodimeter-type instrument. The base side replaces the initial side of a base network.

Orders of networks	Triangulation: Bases: Required accuracy	Triangulation: Bases: Type of instrument	Triangulation: Base sides: Required accuracy	Triangulation: Base sides: Type of instrument	Polygonometry: Required accuracy	Polygonometry: Type of instrument
<u>State geodetic nets</u>						
I-order	1:800,000	--	1:400,000	NASM-2 ЭОД-1	1:300,000	NASM-2 ЭОД-1
II-order	1:600,000	--	1:300,000	NASM-2 ЭОД-1 СВВ-1* СЛД-1**	1:250,000	СВВ-1 СЛД Radio range finder of the Tellurometer type
III-order	1:400,000	ЭОД	1:200,000	СВВ-1 СЛД	1:200,000	Same
IV-order	1:400,000	Same	1:200,000	Same	1:150,000 1:100,000	Same
<u>Local geodetic nets</u>						
Analytical nets						
1-category			1:30,000	СТ-61 Radio range finder of the Tellurometer type	1:10,000	СТ-61 Radio range finder of the Tellurometer type
2-category			1:50,000	Same	1:5000	Same
<u>Survey and connecting nets</u>	Portable radio and light range finders relative to required accuracy (error of measurement of the order of 0.1 m).**					

*In using these instruments an accelerated program is required.

**The Geodetic Service of Czechoslovakia has successfully used range finders to determine photo control points for a large-scale topographic survey.

24. Geodetic instruments and attachments. IN: Novosibirsk. Novosibirskiy institut inzhenerov geodezii, aerofotos"yemki i kartografii. Trudy, no. 15, 1961, 87-101.
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 11, 1962, 11G 253. QB1.A17553

Range Finder Designation

No.	Characteristics	СВВ-1	СДЦ-60	ГД-300	NASM-3 (Swedish)
1	Wt (kg) and dimensions of basic unit	18 50x27x30	24 44x39x46	47 49x37x36	26 55x32x33
2	No. units in set (pieces)	9	8	3	6
3	Power used (watts)	250	120	300 (incandescent bulb) 500 (mercury bulb)	75
4	Error of measurement for n setups (cm) n = 1xp (1 - no. of series, p - no. of setups in series) (2 days)	± (3 + 0.15 Dkm) 36 (4 x 9) ± (2 + 1xDx10^6) 72 (8 x 9)	± (3 + 0.15 Dkm) 12 (4 x 3)	± (10 + 0.15 Dkm) 24 (3 x 8)	± (9 + 0.2 Dkm) 1 (1 x 1)
5	Length of measured lines maximal (km) (when τ = 0.75) minimal	5 (day) 12 (night) 0.75	5 (twilight) 15 (night) 0.5	10 (day) 15-17 (night) 0.15	20 (night) 0.025
6	Accuracy of preliminary data on the length of measured lines (km)	data not needed	data not needed	3 (1.5)	2 40 (f_1)
7	Duration of measurement of one setup (min) one line	1-2 40-60	2-4 40	2-3 40-60	20 (f_2) 60
8	Times expended in processing in field 1 of series (min)	35	30	40	20
9	Accuracy of determination of constants at base with time expended	+ 1 cm 12 series 3 days (in case of divergence with control lines)	+ 1 cm six series 3 days (before and after field work)	+ 5 cm three series 2 days (in case of divergence with control lines)	+ 3 cm three series 2 days (in case of divergence with control lines)
10	Temperature limits of apparatus operation	+30° to -10°	+30° to -10°	+40 to -20°	+30° to -20°
11	Approximate cost (thousands of rubles)	5-5	4-5	8-9	
12	Method of phase indication	visual	photoelectric	photoelectric	photoelectric
13	Error of single fixation of phase	± 5°	± 2°	± 2°	± 0.4°
14	Constant of time indicator (sec)	0.2	6 and 15	1	45
15	Method of solving multivalence	single-step	single-step	three-step	two-step
16	Error of calibrating frequency-measuring apparatus or phase inverter	± 15 kcs	± 15 kcs	± 1°	± 0.2°
17	Effecting range of a spectrum	4800-6250	4500-6250	5800-6400 (IB) 4100-4700 (MB)	4500-6750

Additional comparative data are available from the results of field investigations carried out in 1960 and 1961 by the Novosibirsk Institute of Engineers of Geodesy, Aerial Photography and Cartography. Two of the Soviet range finders compared previously were tested (the СВВ-1 -- 1958 model -- and the СДД-60). A lower-accuracy Soviet model (the ГД-300), and the Swedish NASM-3 were also tested. These range finders are suitable for use in second- to fourth-order triangulation and for polygonometric measurements.

High-Precision Soviet Instruments

25. Nazarov, V. M., V. S. Mikhaylov, and P. Ye. Lazanov. The large ЭОД-1 pulsed-light range finder. Geodeziya i kartografiya, no. 4, 1962, 8-16. QB275.G45
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 11, 1962, 11G 249. QB1.A17553

Experimental ЭОД-1 electrooptical range finders manufactured in 1960 are described. These range finders are designed to measure distances from 5 to 25 kilometers at air temperatures from 0 to ± 35°C with an error no larger than 1:400,000. The range finder outfit includes the following: transmitting-receiving unit (48.5 kg); AF meter (9.5 kg); power unit (18 kg); stand for the receiver-transmitter unit (10 kg); reflector with stand (53 kg); and two electric stations (one for reserve). Photographs of the equipment and a circuit diagram are given, as are the results of a series of test measurements and distance computations. Field tests of five range finders, in which measurements were carried out on lines 5.3, 11.9, and 22.5 km long, showed that the accuracy of the instrument is the same as that of a Geodimeter of the NASM-2A type, and that the ЭОД-1 can be used to lay out State geodetic networks and to measure first-order base sides.

Medium-Precision Soviet Instruments

26. Velichko, V. A. Prospects for using "light radar" for constructing geodetic networks. IN: Moscow. Moskovskiy institut inzhenerov geodezii, aerofotos"yemki i kartografii. Trudy, no. 31, 1959, 31-40. QB275.M63
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 2, 1961, 2G 216. QB1.A17553

Possibilities are described for using polygonometric and linear measurements in triangulation in accordance with the development of various types of pulsed-light range finders. On the basis of

determinations of accuracy for various cases where angle and linear measurements are combined in a triangulation chain, the conclusion is reached that the most suitable case is that in which all angles and an additional side are measured and a Laplace azimuth is determined in the center of the chain. The total displacement of the end point of a chain is 30% less than it is when only angle measurements are made. A possible classification of Geodimeter polygonometry, with an indication of the basic characteristics of first-, second-, third-, and fourth-order polygonometric traverses, is given. Precomputation of the accuracy of Geodimeter and polygonometric traverses shows that first-order traverses are more precise, and that second-order traverses approximate modern first-order chains of triangulation. The following possible scheme of constructing the State geodetic control network is suggested: 1) form a first-order polygon with a perimeter of 800 km by a chain of triangles; 2) divide the polygon into four parts by first-order Geodimeter-polygonometric traverses; and 3) fill in these nets with supplementary second-order traverses and add supplementary third- and fourth-order stations using various combinations of linear and angular measurements. Geodimeters required to carry out these linear measurements can be subdivided into two groups: 1) the large Geodimeter-type instrument and the TsNIIGAiK range finder having an accuracy of not less than 1:250,000; and 2) the average CBB-1 range finder which has an accuracy of not less than 1:100,000.

Results are given for experimental and field work carried out with the CBB-1 range finder in 1956-1957. The length of the longest side measured was 16 km. The mean square error in the measurement of a line with the CBB-1 range finder, evaluated for internal convergence, is $m_D = 2$ cm + $2D \cdot 10^{-6}$, and from evaluations of the true errors (without taking into account errors in triangulation), $m_D = 1$ cm + $5D \cdot 10^{-6}$. The results of measurements of three bases with a range finder show that the relative accuracy of 10-km line measurements was close to 1:200,000. The excellent efficiency of the pulsed-light range finder is pointed out. According to the evaluations the increase in operational efficiency under field conditions using the CBB-1 was not less than 25%, based on the amount of triangulation covering an equivalent area.

27. Ratynskiy, M. V. Some results of investigations of the CBB-1 range finder. IN: Moscow. Moskovskiy institut inzhenerov geodezii, aerofotos"yemki i kartografii. Trudy, no. 45, 1961, 91-105. QB275.M63
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 2, 1962, 2G 118. QB1.A17553

The basic relationships expressing the measurement of distances with the CBB-1 range finder are derived using the compensation method of the extremum. The value of the residual light

flux at the minimum caused by the inequality of the parameters of the Kerr transmitting and receiving capacitors and by errors in the adjustment of the Kerr capacitor and its polaroids is determined. Results of certain experimental investigations (e.g., nonlinearity and variability in scale of the wave meter) are reported. The accuracy of distance measurements made with the CBB-1 is precomputed on the basis of the results obtained (taking into account the main sources of errors and distinctive sensitivities of the eye). The expression $m_D = \pm$ (1 cm + $5 . D . 10^{-6}$) was derived for the error in measuring distances using 24 to 36 setups.

28. Ratynskiy, M. V. Selection of the best operational use of the Kerr capacitor in the CBB-1 pulsed-light range finder for measuring distances by the compensation method of the extremum. IN: Moscow. Moskovskiy institut inzhenerov geodezii, aerofotos"yemki i kartografii. Trudy, no. 46, 1961, 65-67. QB275.M63
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 3, 1962, 3G 171. QB1.A17553

On the basis of formulas developed previously (Referativnyy zhurnal. Astronomiya i geodeziya, no. 2, 1962. 2G 118), computations are made which make it possible to determine the relationship of the observed light source to the frequency modulation and to distance, the value of the residual light source in the minimum, and the form of the minimum. Computations were made for 20 working procedures for the Kerr capacitor which corresponded to

$$p = \frac{U_o}{U_k} = 0.40;\ 0.55;\ 0.70;\ 0.85, \text{ and}$$

$$r = \frac{U_m}{U_k} = 0.10;\ 0.25;\ 0.40;\ 0.55;\ 0.70,$$

where U_o is the polarizing voltage, U_m is the amplitude of the modulating voltage, and U_k is the critical voltage of the Kerr capacitor. Instances of operations without polarizing voltage and with small polarizing voltages were considered separately ($r = 0.40$; $p = 0.00$; 0.05; and 0.10). In contrast to previous work, the integration was performed analytically, not numerically, following a breakdown of expressions of the type $\cos(z \sin\varphi)$ into a Fourier series, the coefficients of which are Bessel functions of the first type. The results obtained were used to compute the accuracy of the visual fixation of the minimum for various operational procedures of the Kerr capacitor. The following limits were derived for the best operational procedure, taking into account supplementary considerations: $0.5 < r < 0.7$; and $0.5 < p < 0.7$.

29. Kondrashkov, A. V. Results of testing the CBB-1 pulsed-light range finder on the MIIGAiK geopolygon. IN: Moscow. Moskovskiy institut inzhenerov geodezii, aerofotos"yemki i kartografii. Trudy, no. 46, 1961, 89-91. QB275.M63
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 3, 1962, 3G 170. QB1.A17553

In September 1959, the 1958 model of the CBB-1 pulsed-light range finder was used on the geopolygon of the Moscow Insititute of Engineers of Geodesy, Aerial Photography and Cartography to measure 5.0 to 11.3-km sides of a geodetic quadrilateral. The measurements were made by the method of compensation of the extremum in the forward and backward directions. The program for each measurement called for 24 readings. The forward measurements were made by the usual program (6 readings on the first minimum, 6 on the second, etc.); the backward measurements were made by a modified program (3 on the first minimum, 3 on the second, 3 on the third, 6 on the fourth, and then 3 on the third, second, and first minima). The mean square errors of the results (computed according to internal convergence) for measurements of sides in the forward direction amounted to ± 2.5 to ± 13.0 cm, and in the backward direction to ± 1.9 to ± 5.6 cm. The mean square errors of the mean of all results of forward and backward measurements were found to be ± 1.8 to ± 4.0 cm. The geodetic quadrilaterals were adjusted by the method of conditional measurements using two variants: in the first variant the sides were assumed to be equally precise; in the second, the sides were assigned weights which were inversely proportional to the square of the mean square error of the measurement. In the first case the corrections had values of -5.0, +1.1, -0.8, -4.7, -0.9, and +5.4 cm; in the second they were -1.7, +1.3, -0.4, -7.6, -1.1, and +5.8 cm. The conclusion drawn was that distances of 5 to 10 km determined with the CBB-1 pulsed-light range finder (using 24 readings) can be measured with errors on the order of 1:150,000.

30. Mikheyechev, V. S. Field tests of the CBB-1 pulsed-light range finder. IN: Moscow. Moskovskiy institut inzhenerov geodezii, aorofotos"yemki i kartografii. Trudy, no. 34, 1959, 129-130. QB275.M63
ABSTRACT: Referativnyy zhurnal: Astronomiya i geodeziya, no. 1, 1961, 1G 212. QB1.A17553

In August 1957 the CBB-1 electrooptical range finder, manufactured at the Moscow Institute of Engineers of Geodesy, Aerial Photography and Cartography, was field tested on a geopolygon near Moscow. A 736-m base was measured in one day using 45 setups with a mean square error of ± 7.2 cm each, and with a final result of

$\pm$ 1.0 cm; the error, compared with results obtained in measuring the base with an invar wire, was +1.5 cm. A 2354-m line was measured in three days using 136 setups; the mean square error in a setup was $\pm$ 13 cm, and in the final result, $\pm$ 1.1 cm. The discrepancy in the length of a line computed from coordinates was +5.0 cm. The scintillation method of measurement was used. Certain defects in the design of the CBB-1 geodimeter are pointed out.

31. Alekseyev, V. I. Control and evaluation of the accuracy of pulsed-light range finder measurements in the field. IN: Novosibirsk. Novosibirskiy institut inzhenerov geodezii, aerofotos"yemki i kartografii. Trudy, v. 13, 1960, 7-16. ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 8, 1961, 8G 206. QB1.A17553

Formulas are proposed for the control and evaluation of the accuracy of distance measurements made in the field with the CBB-1 range finder using the approved method of measurement.

Whole numbers of phase cycles are computed according to results of measurements containing errors (fractional parts) ΔN, which are related to the mean values of the distance in a series by the relationship

$$\Delta N_i = (D_k - D_i)m,$$

from which it follows that

$$\Delta N_1 + \Delta N_4 = \Delta N_2 + \Delta N_3.$$

The equations obtained may be used to check the accuracy of the computed values of distance in the series and the mean of the entire series.

Utilizing the relationship between the mean square error of the arithmetic mean and the difference between the smallest and largest values of the measured value in a given series of measurements, the author obtains a formula for evaluating the accuracy of the measurement of distance according to the maximum and minimum values of the distance in the series

$$M = \pm 0.22 \,|D_k - D|\,\max = \pm 0.22 \,\Delta N\,|\,\max$$

(the number of series is 4). By analogy, a formula is derived for evaluating accuracy for the differences ΔA_{max} of maximum and minimum values of the readings of a wavemeter in the series. By conversion of appropriate formulas the author obtains tolerances for the values ΔN_{max}, $|D_k - D_i|\,\max$, and ΔA_{max} at a given accuracy of

measuring distances. On the basis of the accuracy of measuring distances (and therefore frequency), the author establishes a tolerance for differentiating differences in frequencies which correspond to one phase cycle. The numbers n_k (differences in the number of phase cycles within the limits of a range of a gradual change in frequency) may be checked with the aid of corresponding differences in frequencies. The possibility of applying the indicated methods of checking and evaluating the accuracy of measurements of other range finders with a gradual change in frequency is noted.

32. Demushkin, A. I., M. T. Prilepin, and G. A. Fel'dman. The СДД pulsed-light range finder. Geodeziya i kartografiya, no. 9, 1962, 20-26. QB275.G45

The СДД (Svetovoy Dal'nomer Dvukhtaktnyy) two-cycle light range finder was developed over the past several years at the Central Scientific-Research Institute of Geodesy, Aerial Photography and Cartography. It was designed to measure distances of up to 15 km with a relative error not to exceed 1:100,000. Emphasis was on ease of operation and portability. The special feature of this instrument is that it uses the two-phase circuit of phase comparison proposed by Demushkin. The chief advantage of this circuit over single-phase circuits used in other range finders with photoelectric recording (Geodimeter, ЭОД-1, and ГД-300) is that it makes it possible to compensate for the dark current of the photomultiplier (ФЭУ) and the effect of the background. With a given light source, the signal-to-noise ratio can be increased and the effect of light fluctuation in the atmosphere reduced.

Like other pulsed-light range finders, the principal task of the СДД is to fix the given phase shift being obtained by rounding off the modulated light in laying out two-way distances between the instrument and the reflector.

The experimental model of the СДД consists of two basic units: the receiver-transmitter and the measuring unit. The receiver-transmitter consists of opticomechanical and electronic components. The optical system is similar to that in the ЭОД-1 receiver and consists of a spherical mirror and a mirror-lens component which form the telescopic system, and the lens of the objective set parallel to the path of the rays. The focal plane of the objective coincides with the focal plane of the entire system. The diameter of the free aperture of the objective is 136 mm; the equivalent focal length is 540 mm. In contrast to the ЭОД-1 receiver, the transmitter of the СДД is enclosed, and the mirror-lens component is fastened in glass shields. An СГ-2 bulb supplies the illumination (6 v, 7.5 w). The electronic part is mounted in a separate chassis.

The receiver-transmitter is moved on its support by a screw. Azimuths are measured roughly to 360°, and micrometrically within limits of several degrees. In the vertical plane the instrument can be tilted within the limits of ± 6° by a tangent screw.

Tests carried out in 1961 showed that the experimental model can measure distances of up to 16 km in the dark. Its optimum range was 5 to 12 km. The relative error in distances measuring 5.2 to 15.7 km was 1:350,000; the maximum error was 1:120,000.

33. Alekseyev, V. I. Tables for the computation of distances measured with average pulsed-light range finders having sweep frequency modulation. IN: Novosibirsk. Novosibirskiy institut inzhenerov geodezii, aerofotos"yemki i kartografii. Trudy, no. 14, 1961, 113-118.
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 1, 1962, 1G 189. QB1.A17553

Formulas are given for the compilation of tables designed to convert wavemeter readings directly to lengths of half waves of modulated light (suitable for the CBB-1 range finder). The formulas are given in two variants: one suitable for the preparation of electronic-computer programs and one suitable for use with nonelectronic computers (e.g., calculating machines). The computation of similar tables for the СДД range finder was accomplished with a four-hour work schedule on the "Ural" computer. Compilation of the tables with a calculating machine required about 60 man hours.

Low-Precision Soviet Instruments

34. Bol'shakov, V. D., and V. S. Mikheyevich. Results of extending polygonometric traverses using a ДС-2 range finder. Izvestiya vysshikh uchebnykh zavedeniy. Geodeziya i aerofotos"yemka, no. 4, 1961, 29-37. TA501.I9135
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 8, 1962, 8G 265. QB1.A17553

Technical data are given for the ДС-2 range finder which is designed to measure 0.3 to 3.0-km distances with a mean square error (from three setups) of no more than ± 0.3 m. The ДС-2 is a phased range finder with a continuous variation of frequency modulation and a range of 4.5 to 5.5 mc. The Kerr capacitor serves as modulator and demodulator. Observations are made visually using the compensation method of the extremum. The frequency modulation is determined directly from the scale of the generator which is calibrated with the aid of a luminescent quartz resonator having a frequency of 5 mc. The power required does not exceed 50 watts. The set weighs about 62 kilograms. This range finder was tested on the test polygon of the Moscow Institute of Engineers of Geodesy, Aerial Photography and Cartography in 1960. The constant

correction for the range finder, determined on the basis of a 0.74-km line, was +0.03 m. The ДС-2 was used to measure 18 lines varying in length from 0.5 to 2.3 km (average, 1.32 km). The relative error of the determination of the length of these triangulation or polygonometric lines did not exceed 1:15,000. The mean error of lines measured by the ДС-2 (6 setups) amounted to 0.13 m, and the relative error, to 1:10,000. The dependence of the errors on the lengths of lines is characterized by a correlation coefficient of $r = +0.44$. The anticipated true error for lines 0.5 to 2.3 km long must be precomputed from the formula

$$\Delta_D = \pm (7.2D + 3.5) \text{ cm},$$

where D is the length of the line in kilometers. The ДС-2 was also used to lay out eight polygonometric traverses having a total length of about 34 km, the average length of traverse being 4.2 km and the average length of line, 1.1 km. The average relative error of closure in the traverses amounted to 1:11,000. The inaccuracy of the ДС-2 limits its application. Accuracy can be improved by measuring the frequency modulation to 10 mc or more by installing not less than two crystals in the outer limits of the band for calibrating frequencies determined on the generator scale.

35. Bol'shakov, V. D., V. S. Mikheyechev, and A. I. Demushkin. Results of testing the CT-61 topographic range finder. Geodeziya i kartografiya, no. 5, 1962, 17-21. QB275.G45
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 11, 1962, 11G 87. QB1.A17553

The article states that the ДС-2 and ДСТ-2 electrooptical range finders used for the measurement of short distances can be used to extend polygonometric traverses with errors of closure of not less than 1:10,000. Using the ДС-2 as a base, the Moscow Institute of Engineers of Geodesy, Aerial Photography and Cartography in 1961 produced a model of the CT-61 range finder. A Kerr capacitor was used to modulate and demodulate light; frequency modulation was increased by a factor of four and was brought up to approximately 20 mc.

Phase indications are made visually in accordance with the compensation method of the extremum but the corresponding fix of the phase of the frequency modulation is determined from the scale of the instrument which is calibrated by a quartz (crystal)-calibrator.

The 1961 model was tested on the geodetic polygon of the Institute and in extending the metropolitan polygonometry in the city of Gzhatsk, the sides of which had been previously measured with invar wires. The results of comparisons of lines measured with the wires and those measured with the range finders are given in the table below.

No. of lines	Length of lines	Mean square error		Observer
		absolute	relative	
8	0.21-0.30	2.5	1:10,300	A
8		2.0	1:12,800	B
15	0.31-0.50	2.8	1:14,000	A
15		2.4	1:16,500	B
15	0.51-1.34	2.3	1:30,800	A
16		2.2	1:31,900	B

Results of the investigations show the following: the fourfold increase in frequency modulation led to a fourfold increase in the accuracy of measurements as compared to those made with the ДС-2 range finder; distances of 0.3 to 1.0 km can be measured during the day in sunny weather, 0.3 to 1.5 km in misty weather, and 0.3 to 2.0 km at night; the relative error of a measurement executed with six setups on a line 0.7 km long amounts to 1:30,000; the relative error for a traverse line of from 6 to 10 km does not exceed 1:25,000 for the measurement of turning angles of polygonometric traverses using the OTC theodolite in four setups and for lines measured with a range finder in six setups. The average advance using an automobile is 8 to 10 lines per working day.

36. Voronin, V. A., L. I. Pik, and S. S. Plonskiy. Testing the ГД-300 Geodimeter. Geodeziya i kartografiya, no. 6, 1960, 14-23. QB275.G45
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 1, 1961, 1G 211. QB1.A17553

A brief description is given of the ГД-300 Geodimeter, its distinctive features, and its method of operation. The total weight of the unit is about 250 kg. An incandescent bulb used as the source of light consumes 300 watts, and a mercury bulb, 500 watts; the power is supplied by a Kiyev-2 portable generator. There is a diffraction light modulator with several counter ultrasound radiators. Three fixed-frequency modulators of 10,000, 10,025, and 10,500 mc, which make it possible to resolve ambiguity within a range of 6 km, are used for measuring distances. Phase comparison is effected in a special phase detector at a frequency of 250 kc. The reflector consists of a set of six reflector prisms. The ГД-300 geodimeter can measure distances up to 7 km in bright daylight, 15 km on dull cloudy days, and even longer distances at night. Results of field tests of the ГД-300 Geodimeter conducted in the autumn of 1959 by the Gidroproyekt of the Ministry of Electric Power Station Construction are cited. Altogether, 20 lines, 1 to 15 km in length, representing the sides and diagonals of the skeleton

triangulation laid out in accordance with the program of a second-order triangulation and triangulation of category II, were measured. A single measurement of the line carried out at three frequencies was adopted as one setup. The number of setups in measuring various lines was 11 to 40. Results of an evaluation of the accuracy of internal convergence, and a comparison of data obtained with the Geodimeter and from triangulation showed that the mean square error in a line up to 4 km is ± 7 cm, and in a line of more than 4 km, ± 4 cm. The conclusion is reached that in measuring distances with a mean square error of ± 5 cm, it is necessary to carry out 25 setups which require not more than one hour. Recommendations are made on staffing a survey party and several improvements in the design of the Geodimeter are suggested. The tests showed that the ГД-300 Geodimeter may be used effectively for geodetic work at hydroelectric engineering sites.

37. Popov, Yu. V., I. I. Adrianov, and I. A. Korolev. The small ГДМ pulsed-light range-finder theodolite. Geodeziya i kartografiya, no. 3, 1961, 7-13.* QB275.G45
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 10, 1961, 10G 219. QB1.A17553

As a result of improvement and simplification of the design of the ГД electrooptical range finder developed by the State Optical Institute, a model has been fabricated which makes it possible to measure angles and short distances. The ГДМ range finder utilizes a diffraction-light modulator with several counter-ultrasound emitters. The optical scheme of the modulator includes a light source, an objective, and a modulator. The light source is an incandescent СЦ-118 three-watt bulb with a straight filament about 0.15 mm thick; the transmitting objective is a Jupiter-3 lens with a focal length of 50 m and a relative aperture of 1:1.5; the light aperture of the modulator is 30 mm. The transmitting part of the range finder (light source, objective, and modulator) is attached above the telescope of a ТБ-1 theodolite. The telescope, in addition to its main function, also acts as a receiver for the optical system of the range finder; an iris diaphragm is located in the focal plane of the telescope. The reflected light flux, having passed through the optical-receiver system, is directed by prisms to the cathode of the photomultiplier tube (ФЭУ-17) which is located under the telescope of the theodolite. The zero of the scale of the phase-inverter in the ГДМ range finder (as in the ГД range finders) is determined by means of a system of zero readings for which the light from the modulator is directed into the telescope of the theodolite. The phase-measuring scheme of the ГДМ is essentially identical to that of the ГД model, the only difference being that the conversion of frequency is effected in the ФЭУ; the connection of the heterodyne with the emitter's power supply is

* Full translation available in Geodesy and Cartography, no. 3-4, 1961.

volumetric. The ГДМ range finder has three fixed frequencies of light modulation which are close to 20 mc; there is an intermediate frequency at 250 kc. The phase-measuring circuit is in the form of a separate unit and attaches to the tripod along with the theodolite. The range finder is powered by a storage battery (6 v) through a semiconductor converter set up in the phase-measuring unit. The power consumption is 30 watts. The total weight of the unit, including the theodolite with the range-finder attachment, phase-measuring unit, accumulator, two tripods, and a prismatic reflector, is 38 kg.

The minimum distances which can be measured with the ГДМ range finder are not defined. The maximum distance measured during the daytime was 2.4 km. The maximum distance measured at night was not determined. The mean square error in measuring distances with one setup is ± 22 cm. In measuring distances it is recommended that 30 setups be made. These require no more than one hour to accomplish. Results of the measurement of 14 lines 0.2 to 2.4 km in length (with 5 to 75 setups) using the ГДМ range finder are cited which confirm the aforementioned accuracies. To decrease the effect of the instability of the phase modulation of light with time, it is recommended that the zero reading be made between two readings when measuring from a distance. Three such readings made consecutively at all frequencies comprise one setup for a distance measurement. A method of checking the accuracy of the measurements made by comparing distances obtained in measuring at the different frequencies is recommended.

38. Limberg, A. I. The ГДМ pulsed-light range finder and its field testing. IN: Vsesoyuznyy nauchno-issledovatel'skiy marksheyderskiy institut. Sbornik statey po voprosam marksheyderskogo dela, vyp. 41 (Collection of articles on problems in mine surveying, no. 41). Leningrad, Geodezizdat, 1961. 200-208.
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 12, 1961, 12G 271. QB1 A17553

The pulsed-light range finder is briefly described and results of testing it on a comparator and in open pits of the "Vakhrushevugol'" Trust are given. Results of the measurements of five lines on a comparator are shown in the table below.

Field tests of the ГДМ consisted of measuring nine sides of a fourth-order triangulation and three sides of an analytical net which were determined with an error of the order of 1 50,000. The length of the sides of the triangulation were 0.5 to 1.4 km. The sides were measured with different numbers of setups, ranging from

10 to 134. The relative errors in measuring the sides of triangulation with a ГДМ, computed on the basis of internal convergence, amounted to 1:9600 to 1:47,000, and that of the analytical net, 1:8900 to 1:22,400. In addition, the ГДМ was used in 10 setups to measure a 2.4-km side of a second-order metropolitan triangulation. The discrepancy between the length of the line determined from triangulation and that measured with the ГДМ was 6.5 cm. The mean square error of the ГДМ measurement (for internal convergence) in one setup was ± 19.0 cm, and ± 6.1 cm in the total result. Field tests showed that the ГДМ can be used to conduct observations both day and night; the amount of time spent in measuring a line, regardless of its length, was not more than one hour. A combination in the ГДМ of angular-and linear-measurement features makes it possible to use linear and linear-angular intersections, as well as polygonometric and theodolite traverses, in mine surveying.

Number of setups	Length of line, m	Difference in length of line measured with a tape and with ГДМ	Mean square error for internal convergence, cm	
			in one setup	of result
11	279	-3.9	± 19.5	± 5.6
6	259	-0.6	27.1	11.1
5	239	-2.9	18.3	8.2
8	219	-2.8	12.6	4.4
75	199	-0.9	31.4	3.6

39. Kondrashkov, A. V. An electrooptical range finder with a mechanical modulator. Izvestiya vysshikh uchebnykh zavedeniy. Geodeziya i aerofotos"yemka, no. 3, 1960, 31-36.
TA501.I9135
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 2, 1961, 2G 215.
QB1.A17553

The operational theory of an electrooptical range finder with a mechanical modulator is investigated for postulated triangular-shaped pulses. The law for the change in modulation of the light

flux is expressed in the form of a Fourier series:

$$\Phi = \frac{\Phi_m}{2} - \left(\frac{4\Phi_m}{\pi^2}\right) \sum_{n=0}^{\infty} \frac{\cos (2n + 1) \omega\tau}{(2n + 1)^2}.$$

By introducing the concept of the clarity of the receiving (p_1) and transmitting (p_2) modulators and of the range finder ($p_D = p_1 \cdot p_2$), one will obtain the following expression for the mean clarity of the range finder (which determines the visual reception of light by the observer):

$$P_{mean} = \frac{1}{4} + \frac{1}{2} \left(\frac{4}{\pi^2}\right)^2 \sum_{n=0}^{\infty} \frac{\cos (2n + 1) \omega\tau}{(2n + 1)^4},$$

where $\omega = 2\pi F$ and $\tau = 2D/c$. It follows that the least bright light corresponds to the condition $\omega\tau = (2m + 1)\pi$ or $D = (2m + 1)/4 \cdot c/F$, and the brightest light corresponds to $\omega\tau = 2m\pi$. If we assume that the error of visual fixation of changes of brightness in visible light (and corresponding changes in the clarity of the range finder) amounts to 10%, it follows that, with a change in clarity when $\omega\tau = \pi$, the value of $\omega\tau$ changes by 0.4, and the corresponding error in the distance will be equal to $\Delta D = c\,\Delta(\omega\tau)/4\pi F = 1.2$ m (when $F = 10^7$ cycles).

40. Ratynskiy, M. V. An analysis of the operation of the Kerr cell as a modulator of light flux. IN: Moscow. Moskovskiy institut inzhenerov geodezii, aerofotos"yemki i kartografii. Trudy, no. 40, 1960, 95-102. QB275.M63
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 1, 1961, 1G 284. QB1.A17553

The Kerr cell with intersecting polaroids maintained at 45° may be described by the expression $I = I_k \sin^2 (\pi/2)\, U^2/U_k^2$, where I is the light flux released by the cell, I_k is the light flux falling on the cell, U is the voltage applied to the Kerr capacitor, and U_k is the critical voltage of the Kerr capacitor. The same expression can be expressed as $M = \sin^2 \pi k^2/2$, where $M = I/I_k$, and $k^2 = U^2/U_k^2$. The right side of the last equation is approximated in the interval $0 \leq k \leq 1$ by a polynomial of the fifth degree -- $M' = ak + bk^2 + ck^3 + dk^4 + ek^5$ -- the coefficients of which, determined by the method of least squares, are $a = +0.12967$, $b = -0.51037$, $c = -0.81677$, $d = +7.72153$, and $e = -5.52353$. The deviation $v = M' - M$ in absolute value does not exceed 0.004 and is equal on the average to 0.002.

The problem of the character of the modulation of the light flux from the Kerr cell, in a case when a constant polarizing and sinusoidal modulating voltage is applied to the Kerr capacitor, is investigated with the aid of a polynomial approximating the characteristic of the Kerr cell. The results obtained indicate that the modulated light flux contains a constant component and variable components of basic frequency and upper harmonics. Formulas, graphs, and tables which demonstrate the dependence of the constant component and the amplitudes of the first five variable components of the light flux on the value of the polarizing and modulating voltage are cited.

41. Velichko, V. A. A method for determining the frequency modulation of light corresponding to the light-flux extremum for the measurement of distances by a geodetic phased-light range finder. Author's Certificate, No. 146504, Class 42c, 18. Byulleten' izobreteniy, no. 4, 1962. T285.A32
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 11, 1962, 11G 257. QB1.A17553

The proposal is made that a polaroid be installed in front of the objective of the receiver of the light signals of electro-optical range finders which have modulators like the Kerr cell and visual phase fixing in such a way that it would cover part of the objective, with its principal plane set at a 45° angle to the polarizer and analyzer of the cell, as well as to the optical wedge. In this way, the fixing of the phase modulation of the light flux could be accomplished with comparative clarity of the image of the light source forming the obscured and unobscured parts of the objective.

Czechoslovak Instruments

42. Delong, Bořivoj. Results of the geodetic testing of the MRA 1/CW Tellurometer. Geodetický a kartografický obzor. v. 7, no. 5, 1961, 86-94. QB275.G4
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 12, 1961, 12G 160. QB1.A17553

The Research Institute of Geodesy, Topography, and Cartography, in Prague, in cooperation with the Prague Geodetic and Cartographic Establishment, carried out field tests on an MRA 1/CW-type Tellurometer in 1960. Thirty-one sides were measured with this Tellurometer in two trigonometric networks (13 and 18 sides) 1.0 to 63.3 km long (averaging about 22 km). One series of measurements included two series of "rough" readings (A, B, C, D) carried out on the first and succeeding carrier frequencies and a number of "precise" readings taken at 10 to 12 carrier frequencies. The mean square

error of one series showed little dependence on distance and was within the limits of ± 1.1 to ± 14.5 cm (± 4.5 cm on the average); the mean square error of the final result was ± 0.4 to ± 5.9 cm (± 1.7 cm on the average). The difference between the lengths of sides measured with the Tellurometer and those obtained by triangulation turned out to be of the order of 0.6 to 35.9 cm (about 10 cm on the average). Some of the sides were measured over a period of several days under various meteorological conditions. The investigations showed that, in order to improve accuracy, it was more important to carry out the measurements under varying meteorological conditions than it was to change the site of the station; when meteorological conditions were consistent it was advisable to carry out more than 3 to 4 series of measurements. As a result of the measurement of one line, as a whole or in sections, it was established that the constant correction of the instrument was equal to zero within the limits of accuracy of the measurements. This conclusion was confirmed by the results of the measurements of the sides of the trigonometric networks. A network formed by 18 sides measured with the Tellurometer was adjusted as an independent net. After adjustment, the mean square error of a side equalled ± 8.4 cm; the mean square error of the value for the corrections to the sides was ± 5.3 cm. The difference between the lengths of sides measured with the Tellurometer and those measured by triangulation was reduced, after adjustment, to 1 cm. The combined values of 30 angles obtained by triangulation and computed in terms of sides measured with the Tellurometer are given. The mean square values of the differences in these angles are given in the table.

Lengths of sides	Number of angles	Mean square values of differences		
		U_G-U_T	U_G-U_V	U_V-U_T
6-11 km (average, 8 km)	13	11".67	2".47	12".72
20-36 km (average, 29 km)	17	2.96	2.39	0.98

U_G is the angle obtained by triangulation; U_T is the angle computed in terms of sides measured with the Tellurometer; U_V is the angle computed in accordance with the adjusted sides.

The conclusion reached on the basis of the comparison of the results of measurements made with the Tellurometer and the NASM-2A Geodimeter was that the Geodimeter is at least twice as accurate as the Tellurometer. The results of the Tellurometer measurements were used to compute the value for the velocity of the propagation of electromagnetic waves in a vacuum (C_0 = 299,793 ± 0.3 km/sec).

43. Delong, Bořivoj. Results of geodetic tests of the MRA 1/CW Tellurometer. Geodetický a kartografický obzor, v. 7, no. 6, 1961, 104-108. [No. 42 continued.] QB275.G4
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 3, 1962. 3G 67. QB1.A17553

The MRA 1/CW Tellurometer was used to determine horizontal and vertical control for aerial photographs of an area covering two 1:10,000 quadrangles. A total of 98 stations was determined over a period of 17 working days. The horizontal positionsof the stations were determined by the polar method and the elevations by trigonometric leveling. Distances were measured using three carrier frequencies. Horizontal and vertical angles were measured with a theodolite. The control measurements (14 stations for horizontal position and 23 for elevation) showed that this instrument assures horizontal and vertical measurements having errors of the order of ± 10 cm.

44. Delong, Bořivoj. Geodetic testing of the MRA 1/CW Tellurometer. Studia geophysica et geodaetica, v. 6, no. 1, 1962, 14-40. QC801.S894
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 6, 1962, 6G 166. QB1.A17553

Results of tests carried out by the Research Institute of Geodesy, Cartography, and Topography and the Prague Geodetic and Cartographic Establishment are described. The tests consisted of measuring sides of a geodetic network (first-, second-, fourth-, and fifth-orders) of a base net and also Tellurometer determinations of the coordinates of control points and of trigonometric stations. The measurements of both the geodetic and base nets were made with several complete receptions in which 10 to 12 carrier frequencies were selected. The air temperature, pressure, and humidity were determined at the beginning and end of the reception on both ends of the traverse being measured. Measurements made in one reception took from 5 to 15 min. The number of receptions varied from 4 to 16. Some lines were measured with shifts of the master and slave stations; others were made over a period of several days. The mean square error of one reception on thirteen lines varying in length from 1 to 52 km amounted, on the average, to ± 4.5 cm, and the mean square

error in the value of the difference between lengths measured with the Tellurometer and those measured by triangulation was ± 13.7 cm.

In the base net 18 lines were measured (6 to 63 km); the number of receptions varied from 6 to 24 (8 on the average). The values of the mean square errors of the measurement of one reception and the mean square values of the differences amounted to ± 6.0 cm and ± 14.5 cm. It is pointed out that moving the sites of the stations had no effect on the result of measurements which would be incompatible with the possible effect of meteorological conditions. This was of no particular advantage. The effects of the personal errors of the observers under poor measurement conditions, the tendency of the wet thermometer to show a rise in temperature (up to 1°), and the necessity, in reconnoitering the net, for the Tellurometer to require conditions at variance with those needed for triangulation reconnaissance are noted. As the result of adjusting the base net, both the linear differences in the lengths of sides measured by triangulation and those measured with the Tellurometer were essentially identical. It is noted that the measurements with the Tellurometer were half as accurate as the angular measurements. Twelve sides of triangulation and of the base net had been previously measured with an NASM-2A Geodimeter. The mean value of the difference between the lengths of sides obtained by triangulation and with the Geodimeter amounted to ± 3.8 cm, and to ± 7.0 cm with the Tellurometer. The length of the base, measured with the Geodimeter and the Tellurometer differed from the length previously measured with an invar wire by 1 and 9 mm, respectively, with errors in reception of ± 2.3 and ± 10.6 cm. The velocity of the propagation of electromagnetic oscillations in a vacuum, computed according to the results of the Tellurometer measurements, turned out to be 299,793.2 ± 0.3 km/sec. The Tellurometer measurements of distances to determine the coordinates of control points were made on three modulation frequencies. The determinations of the coordinates and the elevations of control points and of trigonometric points with the Tellurometer and a theodolite to measure angles showed that they can be made with errors of approximately ± 10 cm. The total time required to determine one control point did not exceed 30 to 40 min: 2 min with the Tellurometer, and 10 to 15 min for the measurement of vertical and horizontal angles. Control points measured per day were 4.8 to 7.3. It is noted that the Tellurometer can be used to carry elevations forward in trigonometric work.

45. Polevoy, V. A. Osnovy matematicheskoy obrabotki rezul'tatov radiogeodezicheskikh izmereniy (Principles of the mathematical processing of the results of radiogeodetic measurements). Moskva, Geodezizdat, 1961. 206 p. QB321.P62
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 3, 1962, 3G 176K. QB1.A17553

The theories and methods of solving the principal types of geodetic problems in computing the coordinates of individual features and of geodetic stations being determined by radar and radiogeodetic apparatus are discussed. The book contains the following sections: 1) general information on Tellurometer measurements; 2) preliminary processing of the results of measurements; 3) the reduction of inclined distances to the Krasovskiy reference ellipsoid and to the plane of the Gauss projection; and 4) the computation of the coordinates of features from the results of angle and radio direction-finder measurements, and of the coordinates of points of hyperbolic grids. A special chapter is devoted to the adjustment of geodetic nets measured by trilateration.

F. Levels

High-Precision Soviet Instruments

46. Grishin, B. S. The НБ-2 high-precision level. IN HIS: Yustirovka geodezicheskikh instrumentov (Adjustment of geodetic instruments). Moskva, Geodezizdat, 1962. 154-172.
TA562.G7

The НБ-2 is a high-precision dumpy level with a spirit level, the image of the ends of the bubble of which are distinguished with the aid of the optical system of the objective microscope in the field of view of the reading telescope and viewed in the eyepiece simultaneously with the image of the rod.

In contrast to other high-precision levels (НА-1, НПГ), the plane-parallel plate of the micrometer of the НБ-2 is located inside the telescope and for this reason is protected from external forces and disturbances. The НБ-2 is designed for highly precise and precise leveling.

The vertical axis of the instrument is cylindrical. The elevating screws are of the covered type. Rods used with this instrument are subdivided in 5-mm divisions. The 5-mm divisions are read on the rod through the telescope visually, and the millimeters, tenths, and hundredths of fractions, are read from the drum of the reading mechanism (eyepiece micrometer). The instrument weighs 6 kg; the packing case, 6.1 kg; and the tripod, 8.4 kg. The length of the tripod legs is 1.48 m.

The optical system of the НБ-2 level consists of the optical system of the reading telescope and the optical system of the objective of the microscope level. The optical system of the reading telescope consists of two telescopic systems with a plane-parallel plate installed between them. The first is the most complex of all of the optical systems of the telescopes and consists of two components. The objective of the second system acts as the focusing lens. The first of the two components of the first system, together with the plane-parallel plate, comprise the optical micrometer system. The graticle is etched on one of the plane-parallel plates, with another graticle on the diaphragm. The eyepieces are symmetrical in the telescopes as well as in the microscopes.

The basic characteristics of the reading telescope are: diameter of the free aperture of the objective, 60 mm; equivalent focal length, 458 mm; length of telescope, 422 mm; magnification x49; resolution, $2''.5$; field of view of telescope along vertical, 50'; field of view of telescope along horizontal, 35'; diameter of exit pupil, 1.2 mm; extension of exit pupil, 7 mm; shortest pointing distance, 4.2 mm; limits of focus of the eyepiece, $\pm$ 6 diopters; thickness of the graticle wires, 6 μ; and the rangefinder intercept, 100.

The optical system of the objective of the microscope level consists of a prism unit assembled on the bridge of the prisms, the prisms, the objective of the microscope, and the displacement prisms. The focal length of the objective of the microscope level is 19.99 mm. The field of view of the system is 20 x 11 mm. The magnification of the objective is x0.09. The image of the ends of the bubble of the level is located in the plane of the graticle of the telescope and viewed through the eyepiece of the reading telescope. The magnification of the microscope level is x2.42.

The paths of the rays in the optical system of the microscope level travel as follows: Light, reflected from the mirror, illuminates the spirit level. The bundle of rays from the illuminated ends of the bubble of the level and the scale of the level pass through the objective of the microscope and the displacement prism and fall on the graticle of the reading telescope, where both the image of the ends of the bubble of the level and the scale of the level are viewed through the objective of the microscope.

47. Meshcherskiy, I. N., and I. I. Entin. Investigation of the НБ-4 level. Geodeziya i kartografiya, no. 4, 1962, 32-34.
QB275.G45
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 10, 1962, 10G 235. QB1.A17553

In 1961 an experimental model of the НБ-4 level was investigated by the Central Scientific Research Institute of Geodesy, Aerial P[illegible] Cartography. This instrument is intended for highly [illegible] precise leveling and differs from the НБ-2 and НБ-3 levels in that its reading telescope and spirit level are enclosed in the metallic housing section of the telescope. The purpose of this arrangement is to secure rapid equalization of temperature within the telescope. This should reduce the variation in the angle (i) during the overall and one-sided heating of the level during field operations. The investigation of the dependence of the angle (i) on the heating of the level is described and results are given. Results are compared with similar data obtained from tests of other high-precision levels (see table).

	Variation in angle (i) with temp. variations in 1°			
	НБ-2	НБ-4	Н1004	Н3
Overall gradual heating or cooling	0.6-0".9	0".2	0.2-0".3	0".4
One-side heating or cooling	1.2-1.5	0.4-0.6	0.3	0.5

48. Shakurov, P. F. Precision metal levels. Geodesy and cartography, no. 7-8, 1959, 357-359. (Translated from Geodeziya i kartografiya, no. 7. 1959, 61-64.)

As is known, levels have found extensive use in many branches of science and engineering. The most widely used are the cylindrical and spherical levels, whose bubble tubes are made of glass and filled with some kind of liquid. These levels are fragile, and their sensitivity changes with time as the glass ages.

While occupied with the problem of the exact determination of slopes on the surface of the Earth, the author of this article constructed a level with a design different from all similar instruments. The principle of operation of the new level is as follows. Let us imagine two metal disks d_1 and d which lie one on top of each other, touching each other along a spherical surface facing convexly downward (Figure 1). The radius of curvature of this surface is equal to r. Let air, compressed to 1.3 – 1.4 atmospheres, enter through a tube T and the narrow passage i (diameter 0.1 – 0.2 mm) in the center of the lower disk. Then, because of the impact of the air molecules, the upper disk will separate from the lower disk and slide over it without friction. After some time, when the potential energy of the upper disk is minimum, it will occupy its lowest position.

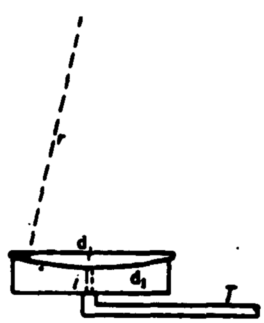

FIGURE 1

The sliding disk is actually a pendulum without a suspension device and an axis of rotation. If the lower disk is inclined at an angle α, the sliding upper disk, whose mass is M, will move a distance of

$$x = \alpha r \qquad (1)$$

Under the action of a quasi-elastic force — the component of gravity —

$$F = M \sin \alpha = M\alpha = \frac{M}{r} \cdot x \qquad (2)$$

the disk will oscillate as expressed by the equation

$$x = A \cos (\omega t + \beta). \qquad (3)$$

Here, x is the deviation of the disk from the initial position,
A is the amplitude of the oscillations,
ω is the angular frequency,
β is the initial phase.

Taking the first ($\dot{x}$) and second ($\ddot{x}$) derivatives of x, we obtain the velocity and acceleration of the oscillations of the sliding disk.

The resistance of the surrounding air to the motion of the disk causes a decrease in the amplitude of the oscillations, i.e., the disk will undergo damped oscillations. Where the velocity of the disk is small, the resistance of the surrounding air can be taken as directly proportional to this velocity, and considered to equal $n\dot{x}$, where n is the coefficient of resistance of the air. The sum of the force of inertia ($M\ddot{x}$), the resistance of the air ($n\dot{x}$) and the quasi-elastic force ($\frac{M}{r}$ x) must always equal zero, i.e.,

$$M\ddot{x} + n\dot{x} + \frac{M}{r} x = 0. \qquad (4)$$

It is known that with damped oscillations

$$x = A_0 e^{-\gamma t} \cos (\omega t + \beta),$$

where γ is the damping coefficient,
A_0 is the initial amplitude,
$A_0 e^{-\gamma t}$ is the instantaneous value of the amplitude.

In our case, γ is a function of the resistance of the air

$$\gamma = \frac{n}{2M}.$$

The layout of the metal level is shown in Figure 2. Here, d is the upper sliding disk, turned from brass. Its lower surface has a very slight curvature. The upper surface of the lower disk d_1 has the same curvature. In the center of the lower disk, an aperture 5 mm in diameter is bored, connecting with a sleeve in the tube of which a diaphragm with a small aperture, 0.1 – 0.2 mm in diameter, is inserted.

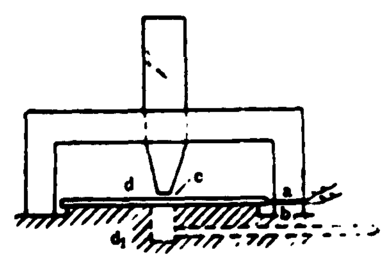

FIGURE 2

The end of the sleeve is inserted in the tube of a rubber bulb. After squeezing the bulb several times, a low pressure is obtained, causing air to flow through the aperture in the diaphragm and to reach the bottom of the upper disk without eddying.

The level can be made in various sizes (for example, from 50 mm to 5 mm).

The sliding upper disk is made with a somewhat larger diameter than the lower disk to prevent dust and foreign bodies from falling on the surface of the lower disk. The entire system is covered with a cap, in the center of which a microscope with a magnification of 100 is placed. The eyepiece micrometer of the microscope consists of concentric circles, relative to which the position of the point c located at the center of the upper disk is determined (Figure 3).

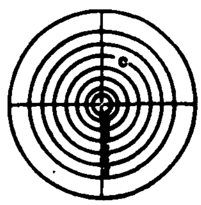

FIGURE 3

If we wish to design an instrument with a definite sensitivity, we can determine the radius of curvature of the spherical surfaces of the disks.

Let us suppose that we are to build a level with a sensitivity such that a displacement of the disk 1 mm to one side would correspond to an inclination of the level of 10". We shall determine for this case the radius of curvature of the spherical surfaces.

According to equation (1), we obtain

$$r = \frac{x\rho}{\varepsilon} = 20.6 \text{ m}.$$

Since the magnification of the microscope is 100, a shift in point c of 1 mm seen through the microscope will correspond to a change in the angle of 0".1. Consequently, the sensitivity of the telescope is 0.1 sec/mm.

To evaluate the possibility of constructing such a system, let us attempt to determine the depth of curvature or rather the value of the concavity of the lower surface, given the determined dimensions.

The diameter of the disk S is seen as an angle φ from a distance r. It is known that the depth of curvature is computed from the formula

$$h = r\left(1 - \cos\frac{\varphi}{2}\right) = 2r\sin^2\frac{\varphi}{4}.$$

Because angle φ is small we take

$$\sin\frac{\varphi}{4} = \frac{S}{4r}$$

and obtain

$$h = \frac{S^2}{8r}.$$

Let S = 65 mm and r = 20.6 m. Then, h = 0.025 mm.

This arrangement, assembled by the author in 1955, showed high sensitivity. To check the sensitivity, the level was placed on the window sill of a stone building. When a weight of 2 grams was placed on the window sill, the disk deviated by one division. After removing the weight, the disk settled back to its former position after a few oscillations.

The measurements showed that the thickness of the layer of air between the disks was 7 microns. In 8 hours of work, about 3 liters of air are used, compressed to about 1.3 atmospheres. With decreasing distance between the disks, the expenditure of air should decrease.

An instrument was constructed with a special device recording slopes on the surface of the Earth with a scale of 0".02 per mm. By decreasing the curvature of the surfaces, it is possible to obtain a sensitivity of $1''.10^{-5}$ per mm.

In addition, a design for a toroidal level was developed, differing in the spherical shape of its surfaces and the method of reading. The toroidal level consists of a block (Figure 4), in which a toroidal recess is made.

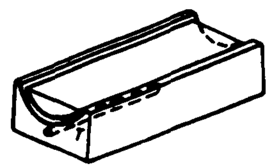

FIGURE 4

Another block is placed inside this recess. A mark is made on the sliding recess, which is examined through a microscope which has a reticle (Figure 5).

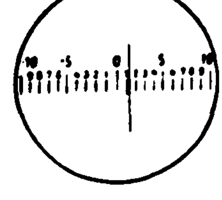

FIGURE 5

During the observations, the mark will oscillate. The zero graduation on the reticle shows the horizontal position of the level as determined at the factory.

When the level is inclined, the mark is deflected to one side or the other from zero by a different number of graduations, for example, by m_1 and m_2. Then, the level will indicate

$$N = \frac{m_1 + m_2}{2}.$$

If the value of one graduation of the level is equal to τ, the level will be inclined with respect to the horizontal plane at

an angle

$$i = \tau N.$$

The computations will be analogous to those of the spherical level.

If the lower disk of the block is welded to the body of the instrument, the adjustment of the level will not be altered.

A metal level is far more accurate and more stable than a glass level, because here there is no glass bulb filled with liquid, no air bubble whose dimensions vary, and no cement used to attach the tube to the holder. When the temperature changes, the dimensions of the piece of metal change evenly in all directions, preserving its geometric shape. Furthermore, a metal level makes it possible to install electric signaling, whereby the electric contacts ab are shortcircuited when the inclination changes (Figure 2).

The spherical surfaces of the disks are easily obtained on a lathe, and they can be made to fit perfectly by grinding or by the methods which have been thoroughly worked out for optical lenses. The polished surfaces can be chromed and, in special cases, covered with gold.

The metal level should find application in precision instruments in geodesy, astronomy, seismology, seismographic geophysical exploration, and other branches of engineering and science.

Medium-Precision Soviet Levels

49. Romanov, L. A. The HC-2 and HC-3 engineering levels. IN HIS: Tekhnicheskiye niveliry (Engineering levels). Moskva, Geodezizdat, 1960. 3-11. TA565.R6

The levels described below are used in the USSR for third- and fourth-order leveling, for engineering projects, and to provide vertical control for topographic surveys. Other levels, generally of the spirit-level type, described in detail in this reference (the HB-1, HГ, HT, and HЛ levels) are not included in this report. These data can be supplied upon request.

Historical Development

The HC-2 (Nivelir sistemy Stodolkevicha-2) level and its successor, the HC-3, are based on a level originally designed by G. Yu. Stodolkevich in 1945 and first issued in 1947 by the experimental workshops of the Central Scientific Research Institute of Geodesy, Aerial Photography, and Cartography as the HTC-46.

The HTC-46 system differed from those of other existing models in that the horizontal crosshair was replaced by the image of the outline of the level's bubble as the rod reading index, and the adjustment of the sighting line in the horizontal position became automatic; neither precise adjustment of the horizontal position nor watching the position of the bubble were required since the image of its outline served as the index in reading the rod and the line of sight adjusted itself automatically in the horizontal posi-

tion. The number of gross errors in determining differences in elevation are reduced, since readings on the rod have to be made only if the index is in the field of view of the level's telescope; measurements can be carried out both in windy weather and on unstable ground (swampy, sandy) without distorting results.

However, the first model had the following disadvantages: 1) the index (image of the outline of the bubble) was both curvilinear and too small, which made reading difficult; 2) large variations in the length of the bubble (characteristic of chambered levels) necessitated frequent adjustments in bubble length and in the index; and 3) the eccentricity of the frame of the telescope objective upset the centering of the optical system, lowering considerably the quality of the image of the rod and necessitating a decrease in the length of the sighting line, which, under certain conditions, greatly complicated the use of the level. These defects required corrections.

In 1951 a new model of the HTC-46 known as the HC-2 was developed and subsequently the HC-3, which incorporated the following change introduced by L. A. Romanov: a cylindrical objective was used to impart a rectilinear shape to the index and to increase its size so that the mutually superimposed images of the opposite ends of the bubble appeared as a long line resembling the horizontal crosshair of the graticle and entirely convenient for making readings on a faced rod. The HC-2 has a compensated cylindrical level which maintains satisfactorily constant the length of the bubble during operations at a station and eliminates frequent adjustment of the index. The objective of the sighting telescope is arranged in a centered frame, which considerably improves the quality of the rod image and makes it possible to operate with a long sighting line.

Measurements made with the HC-2 and HC-3 are free of the inaccuracies inherent in other types of contemporary engineering levels (e.g., those resulting from improper adjustment of the level bubble at zero position at the moment of rod reading and instability of the leveling instrument during operation due to wind or unconsolidated ground). The HC-2 and HC-3 provide the necessary accuracy in leveling, regardless of weather and terrain conditions.

Description

The HC-2 and HC-3 levels have a self-indexing line of sight. They are intended for leveling with the horizontal ray with a mean accidental error of not more than ± 3 mm per km of line with a line of sight up to 75 m, and not more than ± 4 mm with a line of sight up to 100 m. Ordinary leveling rods with centimeter divisions are used with the HC-2 and HC-3.

In the HC-2 and HC-3, the coinciding images of the opposite ends of the bubble appear as a straight line, which serves as the index in reading the rod instead of the usual graticle. Two horizontal cross hairs for determining distances are also in the telescope's field of view. The straight line passing through the index and the principal point in the objective of the sighting telescope (equivalent to the lens) is the line of sight. In leveling, the line of sight remains horizontal even when the telescope is tilted to $\pm$ 90". In addition, the reading index and the image of the rod move in the field of view of the telescope in the same direction and to the same extent, so that the readings on the rod are not affected. The instrument consists of a sighting telescope, a tripod, and a tribrach which is used to fasten the level to the tripod.

The sighting telescope consists of an objective, an eyepiece, a prism contained in the housing, and the focusing lens, which is inside the telescope. The focusing lens is moved by a knob. The housing contains the cylindrical level and an optical system which transmits the images of the ends of the bubble in the field of view of the telescope and the conical axis of rotation of the instrument. A bracket supporting the circular control level and three adjustment screws are attached to the sleeve.

The HC-2 tribrach consists of two plates attached to each other. The upper plate has slots for the footscrews and an opening with an internal thread for the tripod screw in which the sleeve is fastened. The tribrach connects the level to the tripod. The image of the bubble of the level is transmitted to the field of view of the telescope by an optical system consisting of two pentaprisms, two separate prisms, rectangular prisms, and a cylindrical objective. The telescope's eyepiece is displaced relative to the axis, and the coincidence of the rod and bubble images in one focal plane is achieved by a prism. The position of the pentaprism must correspond to the length of a bubble, else the index appears as two parallel lines. Correspondence between the position of the pentaprism and the length of the bubble is achieved by means of a regulating screw. The index must appear as a single line.

The basic characteristics of the HC-series levels are: magnification of the telescope, x31; equivalent focal length of the objective of the telescope, 314 mm; aperture of the objective, 34 mm; field of view of the telescope along the vertical, 60'; field of view of the telescope along the horizontal, 30'; diameter of the exit pupil, 1.1 mm; distance of the exit pupil, 7 mm; magnification of the eyepiece, x25; shortest sighting distance, 3 m; range finder intercept, 100; cylindrical level compensated with a division value of 30" per 2 mm; magnification of the cylindrical objective, x0.022; and the value of one division of the circular level, 7°15' per 2 mm. The HC-2 is manufactured by the "Aerogeopribor" in Moscow.

50. Abissov, A. L. A new self-indexing level. IN: Vsesoyuznyy nauchno-issledovatel'skiy marksheyderskiy institut. Sbornik statey po voprosam marksheyderskogo dela, vyp. 41 (Collection of articles on problems in mine surveying, no. 41). Leningrad, Geodezizdat, 1961. 188-199.
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 12, 1961, 12G 265. QB1.A17553

The design of the НЗК-1 level with a mirror compensator, developed by the All-Union Scientific Research Institute of Mining Surveys, is described. The НЗК-1 level is designed for third- and fourth-order surface leveling and for the first and second categories of underground leveling. The principal technical characteristics of the level are: magnification of the reducing telescope, x28; field of view, 1°20'; diameter of the aperture of the objective, 40 mm; resolving power of the telescope, 4"; focal length of the objective, 256 mm; shortest sighting distance, 1.5 m; value of the graduations of the circular level for preliminary adjustment of the instrument, 15', damping time of compensator vibrations, 0.5 to 1 sec; limits of operation of compensator, ± 20' and ± 25'; coefficient of range finder, 100; and the weight of the instrument (without case), 1.9 kg. A flat mirror with a surface coating is located between the three-lens objective and the focusing lens, which changes the direction of the sighting line to 90°. The compensator, a flat mirror suspended on four filaments made from beryllium bronze, is situated above the telescope's objective. The ends of the filament are attached to tongs. The upper tongs are attached to guide strips which can be moved longitudinally (in adjusting the compensator). A metallic casing and protective cover glass protect the mechanism of the compensator and the objective from the effects of the outside medium. The compensator is equipped with an air damper and a vibration-stopping device. The clearance between the walls of the damper cylinder and the piston is 0.15 mm.

Control tests of the НЗК-1 level are examined and the results reported. Laboratory investigations have shown that the mean square error in reading the rod, which includes the error in setting the sighting axis in the horizontal position and errors in pointing and reading, is approximately 1".5. Errors of closure in leveling lines run at various industrial sites were found to be considerably smaller than the permissible errors. The operating efficiency of the НЗК-1 level is 1.5 to 2 times greater than that of levels of older design. The optimum distance from the level to the rods is 70 to 75 m.

51. Abissov, A. L. H3K-1 level with a self-indexing sighting line. Gornyy zhurnal, no. 5, 1961, 73. TN4.G8 1961
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 8, 1961, 8G 274. QB1.A17553

A level with a mirror compensator, designed at the All-Union Scientific Research Institute of Mining Surveys, is described. Technical data on the H3K-1 level are as follows: magnification of the telescope, x28; field of view, 1°20'; free aperture of the objective, 40 mm; focal length, 256; shortest sighting distance, 1.5 m; value of a division of the circular level, 15'; limits of operation of the compensator, ± 20'; time of waning of vibrations of the compensator, 0.5 to 1 sec; and weight of the instrument, 1.9 kg. The compensator is situated in front of the objective of the telescope in a special housing. It consists of a mirror fastened to the body, four thin metallic tapes, and a cylindrical air damper. Field tests of the H3K-1 level showed that it may be used for third- and fourth-order leveling on the surface and categories I and II in mines. Productivity in working with the H3K-1 as compared with an ordinary level is increased 1.5 to 2 times. Optimum distance from the level to the rods is 70 to 75 m.

52. Churilovskiy, V. N. Theoretical bases for the operating principle of a self-indexing level with a vertically suspended mirror. IN: Vsesoyuznyy nauchno-issledovatel'skiy marksheyderskiy institut. Sbornik statey po voprosam marksheyderskogo dela, vyp. 41 (Collection of articles on problems in mine surveying, no. 41). Leningrad, Geodezizdat, 1961. 134-145.
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 3, 1962, 3G 283. QB1.A17553

The small range of the angle of inclination of the axis of the instrument and the sensitivity of the compensator to temperature changes are described as the principal shortcomings of present models of the self-indexing level. In order to overcome these deficiencies, a design was proposed for a compensator which consists of four flat mirrors, three securely fastened to the instrument and the fourth (the compensator itself) suspended vertically by two short bent wires. The mirror compensator is located between the two telescope systems parallel to the light rays. The optical design of the reading telescope of the proposed level is given. The operating principle of the compensator is discussed and errors peculiar to a self-indexing level during longitudinal and lateral inclination are investigated.

53. Batrakov, Yu., V. D. Yeremeyev, and L. B. Savinov. Investigation and field use of the НЛ-3 level. Geodeziya i kartografiya, no. 11, 1961, 29-32. [Translation available]
QB275.G45
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 4, 1962, 4G 53. QB1.A17553

To test its performance, the НЛ-3 was used to run an inclined line between 39 bench marks to determine differences in measuring elevations (h_o) by geometric leveling using a third-order program and with the НЛ-3 (h). The mean square errors, computed according to the differences ($h - h_o$), were $\pm$ 8.2 mm/100 m and $\pm$ 26 mm/km. The НЛ-3 also was used to run 114 lines of levels between bench marks the heights of which were determined by fourth-order leveling. The lengths of the traverses varied from 0.3 to 9.4 km, and the total length of all lines was 578 km. The mean square error of determination of relative elevations with the НЛ-3 was about 8 cm/km. It was established that with the НЛ-3, in computing permissible errors of closure of leveling lines used to run lines over which the line of sight was up to 250 m, the value $f_{permiss} = \pm 18 \sqrt{L}$ cm, where L equalled the length of the line in kilometers. The НЛ-3 can also be used for level control, for aerial photographs, and for controlling mosaics.

East German Levels

54. Neubert, K., and W. Werrman. Testing the operation of the Koni-007 level at the Mine Surveying Institute and in field use. Vermessungstechnik, v. 10, no. 3, 1962, 69-75.
TA501.V38
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 11, 196[illegible], 11G [illegible] QB1.A17553

The results of the investigations made by the Zeiss People's Establishment of the Koni-007 level are described. Rods were set up successively at 10, 15, 45, 50, 60, and 70 meters from the instrument to determine the pointing error. Five series of observations with 10 pointings were carried out for each of the distances; the mean square errors of one pointing on the rod divisions were found to equal $\pm$ 0.023, $\pm$ 0.030, $\pm$ 0.079, $\pm$ 0.101, $\pm$ 0.125, and $\pm$ 0.169 mm, respectively. The error of installing the compensator was determined simultaneously with the errors of pointing at the sighting target. For this purpose the hair of the graduated micrometer, installed in the laboratory 8.5 m from the instrument, was used. The value of $m_o = \pm 0''.19$ was obtained. The error of pointing on the hair of the micrometer was also determined in order to distinguish it from the operating range of the compensator (when the cutoff device is not present); the value was found to equal $m_z = \pm 0''.12$. Thus, the mean square error of the installation of the compensator, computed in accordance with the formula

$m_k = \pm \sqrt{m_0^2 - m_z^2}$, amounted to $\pm$ 0".15. The operating range of the compensator was about 12'. The instrument worked better tilted laterally than tilted forward. The mean square error of the setting of the circle level, determined with the aid of an examiner, equalled $\pm$ 24". Repeated leveling, using one position of the instrument and of the rods, was carried out instead of reciprocal leveling to determine the inclination of the line of sight σ. The result obtained was: σ = +0.312 mm/km = 0".0644. The error of the "zero point" δ (the error corresponding to the error caused by angle (i) in instruments having levels) was investigated 15 times at distances of 15—30—30—15 m. The limiting values of δ were +7".42 and -5".08. The mean square error of the determination of δ was $\pm$ 0".82. The relationship between δ and temperatures was not established. Altogether, 46.4 km of lines of reciprocal leveling were run, forming a system of polygons. The mean square kilometric error of the reciprocal leveling in terms of the error of closure of the polygons amounted to $\pm$ 0.44 mm. The work was executed at a rate of 1.11 km/hr. Along hard-surface roads the instrument was set up 26 times per hour, and 14 times per hour on steep slopes. When the line of sight was 30 m, 243 seconds were required; when it was 40 m, 264 seconds were required.

55. The Ni-2 level. Eisenbahntechnische rundschau, v. 11, no. 4, 1962, 47. TF3.E18
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 8, 1962, 8G 124. QB1.A17553

The advantages of using the Ni-2 for leveling along railroad beds are pointed out.

APPENDIX A

GEODETIC INSTRUMENTS MANUFACTURED IN SOVIET-BLOC COUNTRIES

Zeiss Geodetic Instruments

1. Vyskočil., Geodetic instruments, devices, and equipment. Geodeticky a kartograficky obzor, v. 7, no. 12, 1961, 238. ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 7, 1962, 7G 231. QB1.A17553

Instruments and equipment manufactured by Zeiss are enumerated. They include the following theodolites and levels:

Theo 120-small theodolite;

Theo 020-1' theodolite with self-indexing vertical circle;

Theo 010-theodolite;

Ni 060-low-accuracy level;

Ni 030-engineering level (mean square error per km of reciprocal line, ± 2-3 mm, and ± 0.8 mm when used with a micrometer having a plane-parallel plate;

Koni 007 level with a self-indexing line of sight (mean square error per km of reciprocal line, with a micrometer, ± 0.5 to 0.8 mm, and without a micrometer, ± 2 to 3 mm);

Ni 004 high-precision level (mean square error per km reciprocal line: ± 0.4 mm);

3- and 1.75-m invar rods for precision leveling;

Teletop range finder;

Lotakeil 004 range finder;

Dimesskeil 002 range finder;

Rodta 002 reducing tachymeter, and the Dahlta 020 C reducing tachymeter, both with additional tables for semi-automatic pointing on [illegible] with an accuracy of ± 0.1 mm;

BRT 006 reduction tachymeter;

and the Photheo 19/1318 phototheodolite.

2. Jobst, Rudolf. New instruments of the Zeiss People's Establishment at the 1961 technical exhibit in Leipsig. Monatsschrift für feinmechanik und optik, v. 78, no. 3, 1961, 85-90.
ABSTRACT. Referativnyy zhurnal. Astronomiya i geodeziya, no. 6, 1962, 6G 241. QB1.A17553

The Theo 120 theodolite, the BRT006 base-reduction tachymeter, the meridian finder, the stereometrograph, coordinatometer, and other instruments and devices shown at the exhibit by the Zeiss People's Establishment, are described briefly.

Czechoslovak Instruments

3. Michalčák, Svatopluk. Czechoslovak geodetic instruments. Geodetický a kartografický obzor, v. 7, no. 11, 1961, 213-217.
ABSTRACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 6, 1962, 6G 242. QB1.A17553

The development of geodetic instrument construction in Czechoslovakia is reviewed. Short descriptions are given for the geodetic instruments issued in Czechoslovakia up to 1945 (the "Duplex" 1' theodolite, the Frić 9RN 30" tachymeter, the Frić-13 1' tachymeter, and the TN-25 20" theodolite) and after 1945 by the People's Establishment, Meorta, in Prague (a 30" theodolite with the Th x30 vernier, the N x30 level, the T 1c optical theodolite, the MT-10 1' theodolite with a scale microscope, the MT-20 10" theodolite with an eyepiece micrometer, and the MN-20 level with a self-indexing pointing axis).

Hungarian Geodetic Instruments

4. Zeeman, Josef. Hungarian geodetic instruments of recent manufacture. Geodézia és kartografia, v. 7, no. 12, 1961, 230-237.
ABSTFACT: Referativnyy zhurnal. Astronomiya i geodeziya, no. 7, 1962, 7G 233. QB1.A17553

APPENDIX B

The following is a reproduction of a translation of the Basic Regulations on the Establishment of the State Geodetic Network of the USSR published in Geodesy and Cartography, no. 9, 1961, 406-410. (Translated from Geodeziya i kartogoafiya, no. 9, 1961, 8-14.)

§1

The State geodetic network of the USSR is the chief geodetic base for topographic surveys at all scales and should satisfy the requirements of the national economy and the defense of the country for the solution of appropriate scientific and technical engineering tasks.

§2

The State geodetic network is established by the methods of triangulation, polygonometry, trilateration, and combinations of them.

In each region the establishment of the geodetic network should be effected by that method which provides the maximum economy of energies and expense. Exception to this rule is permitted when the work is of an urgent nature.

§3

The State geodetic network is subdivided into first-, second-, third- and fourth-orders.* They differ from one another in the accuracy of the measurements of angles and distances, the length of the sides in the network, and the sequence in which they are subsequently developed.

The State first-order geodetic network, the astronomic-geodetic network, is intended for scientific investigations associated with the determination of the figure and dimensions of the earth and for the extension of a uniform system of coordinates over the entire territory of the USSR. The State first- and second-order geodetic networks are the basis for the development of networks of lower orders. The State third- and fourth-order geodetic networks are used to expand control networks.

The establishment of the State geodetic network is usually executed in accordance with the principle of transition from the general to the particular.

§4

The State first-order geodetic network is established in the form of polygons having perimeters of 800 to 1,000 km formed by triangulation or polygonometric links** no longer than 200 km, and located, insofar as possible, along meridians and parallels.

A first-order triangulation link consists of triangles, close to equilateral, or of a combination of triangles, geodetic quadrilaterals and central-point systems. The lengths of the sides in first-order triangulation links usually should be no shorter than 20 km. Base sides[1] are measured at the ends of first-order triangulation links. Laplace stations are determined at both ends of the base sides (at the apexes of the polygons).

A first-order polygonometric link should be extended linearly and consist of no more than 10 sides having a length of the order of 20 to 25 km. Laplace stations are determined at both ends of the extreme sides of the links (at the apexes of the polygons).

§5

The mean square error of the measured angles at the stations of first-order triangulation links should be no more than ±0".7 (in the error of closure of the triangles) and no more than ±0".4 at first-order polygonometric stations (from processing of the results of measurements at the stations).

§6

The mean square errors in the lengths of the base sides of first-order triangulation links should not exceed 1:400,000, and in the lengths of the sides of first-order polygonometric links — 1:300,000 (from the processing of the results of measurements at stations).

The measurement of the base sides in triangulation links and of sides in first-order polygonometry is accomplished with a precision geodimeter-type instrument.

In individual cases:

a) the measurement of the lengths of the base sides can be accomplished with a first-order Yederin apparatus,

b) in lieu of base sides it is possible to determine initial sides from base networks in which the bases are measured with a first-order Yederin base apparatus with an error of no more than 1:1,000,000. The error of the computed initial sides should not exceed 1:400,000.

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*In this journal the Russian word "klass" is translated as "order" when used in connection with triangulation or leveling. Russian "orders" are not necessarily equivalent to U.S. "orders". (Ed.)

**The Russian term used here, "zveno", means a section in arc triangulation of area triangulation, as used and defined in U.S.C.&G.S. Special Publication, No. 242. (Ed.)

[1]"Base side" is the term given to a side of triangulation measured directly by a Yederin base apparatus or a geodimeter-type instrument. The base side replaces the initial side of a base network.

§7

The mean square errors of determinations at Laplace stations should not exceed:

in astronomic latitude	—	±0''.3,
in astronomic longitude	—	±0^s.03,
in astronomic azimuth	—	±0''.5.

Errors in determinations are computed from the results of measurements at stations, taking the error of the personal equation into consideration when determining longitude.

§8

It is possible to establish a continuous network of first-order triangulation in certain regions in lieu of polygons formed by triangulation links or first-order polygonometry. The length of the sides in continuous first-order networks is determined depending on the physical-geographic conditions and the particular density of stations but, as a rule, it cannot be less than 20 km.

Continuous triangulation nets or first-order polygonometry, in case of necessity, can be established in polygons laid out in accordance with §4.

The base sides and Laplace stations in continuous first-order networks are determined approximately every 10 sides.

In first-order networks the accuracy of the measured angles, sides, and astronomic determinations should correspond to the requirements indicated in §5, 6 and 7.

§9

At stations of the State first- and second-order geodetic network coinciding with the principal astronomic-gravimetric leveling lines, the astronomic latitudes and longitudes are determined in accordance with the program for astronomic-gravimetric leveling.

The principal astronomic-gravimetric leveling lines are:

1. Pulkovo—Nikolayev;
2. Pulkovo—Belomorsk;
3. Glazov—Vorkuta—Salekhard;
4. Vil'nyus—Orsha—Vyaz'ma—Ul'yanovsk—Ufa—Chelyabinsk— Novosibirsk—Krasnoyarsk—Tayshet;
5. Drogobych—Kiev—Belgorod—Kalmykovo—Temir—Balkhash—Udzhar;
6. Karsakpay—Ura Tyube;
7. Tayshet—Vitim—Suntar—Ust'ye Vil'yuya—Tiksi;
8. Tayshet—Irkutsk—Chita—Skovorodino—Khabarovsk;
9. Kurgan—Salekhard;
10. Krasnoyarsk—Dudinka;
11. Tiksi—Nizhne-Kolymsk.

The mean square errors in astronomical latitudes and longitudes should not exceed the values shown in §7.

§10

The State second-order geodetic network is established in the form of triangulation networks, completely covering the triangles of a polygon, formed by triangulation links or first-order polygonometry.

The sides of the triangles in a second-order network may have a length of from 7 to 20 km.

The selection of the length of the sides of the triangles in each individual case should be justified.

The length of the sides in a second-order network can be increased in those cases when individual sections of the net coincide with large swamps which are difficult to traverse, water bodies, high mountains, and regions with shifting sand.

The establishment of the State second-order geodetic network by the polygonometric method will be executed in each individual case in accordance with a specially developed program.

§11

The mean square error in the measured angles at stations in the second-order net should not exceed ±1''.0 (in triangulation — from errors of closure of triangles, and in polygonometry — from errors in closure of the closed figures).

§12

Base sides in continuous second-order triangulation nets should be evenly distributed and not less than every 25 triangles apart and one base side should be situated approximately in the middle of the polygon.

The relative error in the base sides should be no more than 1:300,000, and in the sides of a polygonometric net — 1:250,000 (from processing data at the station).

§13

In a second-order network, Laplace stations are determined at the ends of the base side or the side of a polygonometric network located in the middle of a polygon. The accuracy of the determination of the astronomic latitudes, longitudes and azimuths should satisfy the requirements in §7.

§14

The stations of the State third- and fourth-order triangulation networks are determined relative to stations of higher orders by the insertion of rigorous systems[2] or individual stations. The lengths of sides, as a rule, should be: in third-order triangulation nets — 5 to 8 km, in fourth-order networks — 2 to 5 km. In all cases, the distances between stations not connected by measured directions belonging to adjacent systems should not be less than: in third-order networks — 4 km, and in fourth-order networks — 3 km. The determination of stations in third-order networks, as a rule, should be accomplished by the system of insertion.

In establishing third- and fourth-order networks by the polygonometry method the determination of stations of the appropriate order is accomplished by laying out systems of traverses or individual traverses tied to stations of a higher order.

In this case there should be no more than two turning points between points of intersection or between points of intersection and initial points. The shortest side of a third-order traverse is 3 km; for a fourth-order traverse it is 2 km.

If the distance between stations corresponding to different traverses is less than 4 km in a third-order network and less than 3 km in a fourth-order network, provision should be made for their mutual connection.

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[2]In a general case the term "rigorous system" means a net so laid out that newly determined stations have connections with all stations of a higher order or of the same order situated in the immediate vicinity.

§15

The measurement of angles at third- and fourth-order stations should be executed with the following mean square errors: in third-order networks, no more than ±1".5, and in fourth-order networks, no more than ±2".0 (based on the errors of closure of the triangles or closed figures).[3]

The mean square errors of the measurement of the lengths of the sides of third-order polygonometric traverses should not exceed 1:200,000 and should not exceed 1:150,000 for fourth-order traverses (based on the results of measurements at the stations.[4]

§16

If third- and fourth-order networks are being developed in small sections as isolated continuous triangulation networks, then the base sides in such networks are measured every 20 to 25 triangles, but there are to be no less than two base sides. The mean square error in the base sides should not exceed 1:200,000.

Third- and fourth-order polygonometric networks in this same case are established with polygons having the following perimeters: in third-order networks — no more than 60 km, and in fourth-order networks — no more than 35 km.

The connection of isolated networks with networks of higher orders is accomplished during the development of the latter.

§17

The establishment of the State first- and second-order geodetic network should be executed in accordance with a unified long-range plan and in the prescribed sequence.

In the establishment of the State first- and second-order geodetic network, provision should be made for their mutual connection into a single whole and breaks should not be permitted between the networks of adjacent links and networks if they are located closer than 50 km from newly planned networks.

In polygons which are close in size to normal polygons, if more than half-covered by a second-order network, provision should be made for covering the remaining part of the polygon with first- or second-order networks in the immediate future.

§18

The elevation of each station in the State geodetic network should be determined by direct *** or trigonometric leveling.

§19

Two azimuth (reference) points (with subsurface marks) must be established at each station in the State geodetic network at distances of 500 to 1,000 m from the station (no closer than 250 m in the forest). In isolated cases a geodetic tower of local landmark (tower spire, bell tower, mosque, etc.), situated no more than 2 or 3 km from a station in the State geodetic network, can be used as one of the azimuth marks it if it clearly visible from the ground to the base. The angles between adjacent sides of the network and the directions to the azimuth marks should be measured with a mean square error of no more than ±2".5.

§20

The establishment of the State geodetic network by the method of trilateration is executed in accordance with a scheme and procedure worked out in each individual case after taking into consideration the physical-geographic and other conditions in the work area.

§21

The following norms are established for the density of stations in the State geodetic network to serve as control for topographic surveys:

for surveys at a scale of 1:25,000 and 1:10,000	— one station every 50 to 60 square kilometers,
for surveys at a scale of 1:5,000	— one station every 20 to 30 square kilometers,
for surveys at a scale of 1:2,000 and larger	— one station every 5 to 15 square kilometers.

The norm of a density of one station for 50 – 60 square kilometers, as a rule, is established for laying out first-, second-, and third-order networks.

The density of stations in the State geodetic network in areas which are difficult-of-access can be decreased depending on local conditions and requirements, but by no more than one and one-half times.

Surveys in small areas at the scales mentioned above may be made only on survey control, that is, without developing the State geodetic network.

Specific directions on establishing the density of stations in the State geodetic network are contained in the current instructions on the execution of topographic surveys.

§22

In the areas of cities having no less than 100,000 inhabitants or occupying an area of not less than 50 square kilometers within the city limits, the State geodetic net is planned in such a way that there will be one station, on the average, every 5 to 15 square kilometers and, in the event that the network within the city is already developed at the time work begins, it should be reliably tied to the All-Union geodetic network.

§23

In those cases when it seems advantageous in technical and economic respects in a particular area, the following are

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[3] All three angles are measured in the triangles of triangulation of all orders.

[4] In individual cases, for third- and fourth-order polygonometric sides, whose lengths are close to the minimum, the permissible relative errors can be 1:150,000 and 1:100,000, respectively.

***The Russian term used here literally means "geometric". In U.S. usage, this may refer to spirit leveling although they also use the phrase "spirit-leveled," ("nivellirovannyy spirtovym urovnem"), as well. (Ed.)

permitted:

a) the State geodetic network may have a density of one station per 50 to 60 or more square kilometers, only when second-order networks are being established;

b) where there are no first- and second-order stations, with only third-order networks being established, the density may be one station every 20 to 30 square kilometers;

c) where there are no first-, second-, and third-order stations, with only fourth-order networks being established, the density may be one station every 5 to 15 square kilometers;

d) where there are first- and second-order stations, fourth-order networks may be established, bypassing third-order networks, with a density of one station each 5 to 15 square kilometers.

The directions in points b) and c) of this paragraph are applicable to cases when the area of the geodetic control does not exceed 3,000 square kilometers. Established third- and fourth-order networks are subject to connection with a network of a higher order when work is done in adjacent sectors.

§24

The stations of the State geodetic network are marked by especially reliable subsurface structures (disks).

§25

Linear measurements in the State geodetic network should be related to the length of the three-meter bars Nos. 541 or No. 613 which are calibrated annually against the USSR standard meter bar No. 28.

§26

The coordinates of all stations in the State geodetic network are computed in a uniform system of geodetic coordinates — "in the 1942 system", established by a Decree of the Council of Ministers of the USSR of 7 April 1946, No. 760.

The initial data of this system are:

a) the Krasovskiy reference ellipsoid — major semi-axis 6,378,245 m, flattening 1:298.3;

b) the elevation of the geoid at Pulkovo above the reference ellipsoid is equal to zero;

c) the geodetic coordinates of the Pulkovo Observatory (center of tower A);

d) the geodetic azimuth from Pulkovo (tower A) to Bugry station (Sablinskaya base network).

The geodetic network in regions remote from the general national network can be computed temporarily from a local initial geodetic station. In such cases the network in question should be connected with the national network as soon as possible.

§27

Rectangular coordinates for all stations in the State geodetic network are computed on a plane in the Gauss projection in 6° zones. The axial meridians of the 6° zones are 21°, 27°, 33°, ..., 183°, ..., 177°.

The origin of the coordinates in each zone is the point of intersection of the axial meridian with the equator; the value of the ordinate on the axial meridian is assumed to equal 500 km.

§28

In regions of surveys at a scale of 1:5,000 and larger, rectangular coordinates in 3° zones are computed for the stations of the State geodetic network, in addition to the rectangular coordinates in 6° zones. The axial meridians of the 3° zones are 18°, 21°, 24°, ..., 177°.

Exceptions to this rule are specified in the appropriate instructions or regulations.

§29

The State geodetic networks, before their adjustment, should be referred to the surface of the Krasovskiy reference ellipsoid, for which appropriate reductions are introduced into the lengths of measured lines and into the angles of first- and second-order networks and, in cases of necessity, in networks of lower orders.

§30

All State geodetic networks are subject to adjustment in the 1942 system of coordinates during the year following the year of completion of the network in each section.

The final coordinates of stations in the State geodetic network are computed as soon as possible, as first- and second-order networks completely cover the polygon of an astrogeodetic polygon whose stations have coordinates computed in the course of common adjustment of the astrogeodetic network.

If the geodetic networks do not completely cover a polygon of the astrogeodetic network, or if they are adjusted within a polygon which was not included in the common adjustment of the astrogeodetic network, the coordinates of the stations in the adjusted network are considered preliminary.

A new adjustment of the astrogeodetic network should be made within two or three years after completion of the astrogeodetic network. This adjustment should include triangulation links, polygonometric work, and continuous first-order networks, the principal, up-dated second-order triangulation chains, and also — in suitable form — continuous second-order networks completed before the beginning of the adjustment of the astrogeodetic net and which were established in accordance with the Basic Regulations of 1954 and these current Basic Regulations.

The over-all adjustment of the astrogeodetic network and the adjustment of second-, third- and fourth-order networks is made in accordance with the instructions in special regulations.

§31

Catalogs of the coordinates of stations in the State geodetic network are prepared and published in accordance with established procedures.

§32

It is permissible to establish a special-purpose network in accordance with a procedure worked out for each particular case for controlling a number of engineering operations which require especially high accuracy of the geodetic network, or if it should be of a specific construction.

§33

Second-, third- and fourth-order triangulation, established in accordance with the "Basic Regulations of 1939", are covered by a new network only in those cases where their accuracy and the density of stations does not satisfy the requirements of the scheduled topographic-geodetic work.

In individual cases the density of stations can be increased to the required density by the insertion of additional stations of the required accuracy.

§34

The marks of all orders and determined reference features in the State geodetic network are subject to regular inspection in accordance with the Decree of the Council of Ministers of the USSR of 4 December 1951, No. 4948. The restoration of the external identification of stations should be accomplished during each inspection.

In the event of the destruction of the reference features, the latter are usually re-determined.

§35

The field men in charge of angle and linear measurements and astronomic and gravimetric determinations should be geodetic engineers or, in exceptional cases, geodetic technicians who have had appropriate experience in this particular work.

§36

These "Basic Regulations on the Establishment of the State Geodetic Network of the USSR" are called the "Basic Regulations of 1954-1961".

The basic regulations were drawn up by a commission made up of the following persons: S.G. Sudakov, T.F. Aleksandrov, A.I. Bulanov, A.I. Durnev, S.V. Yeliseyev, P.S. Zakatov, A.A. Isotov, G.M. Karlov, B.S. Kuz'min, A.D. Kukushkin, A.P. Kolupayev, Ye. A. Kozlova, B.A. Larin, D.A. Larin, B.A. Litvinov, A.V. Mazayev, L.P. Pellinen, A.I. Petrov, A.I. Solov'yev, A.F. Tomilin, S.S. Uralov, M.S. Uspenskiy, M.P. Fomin, V.N. Shishkin, and A.P. Shcheglov.

13 June 1961 S. Sudakov, Commission Chairman

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